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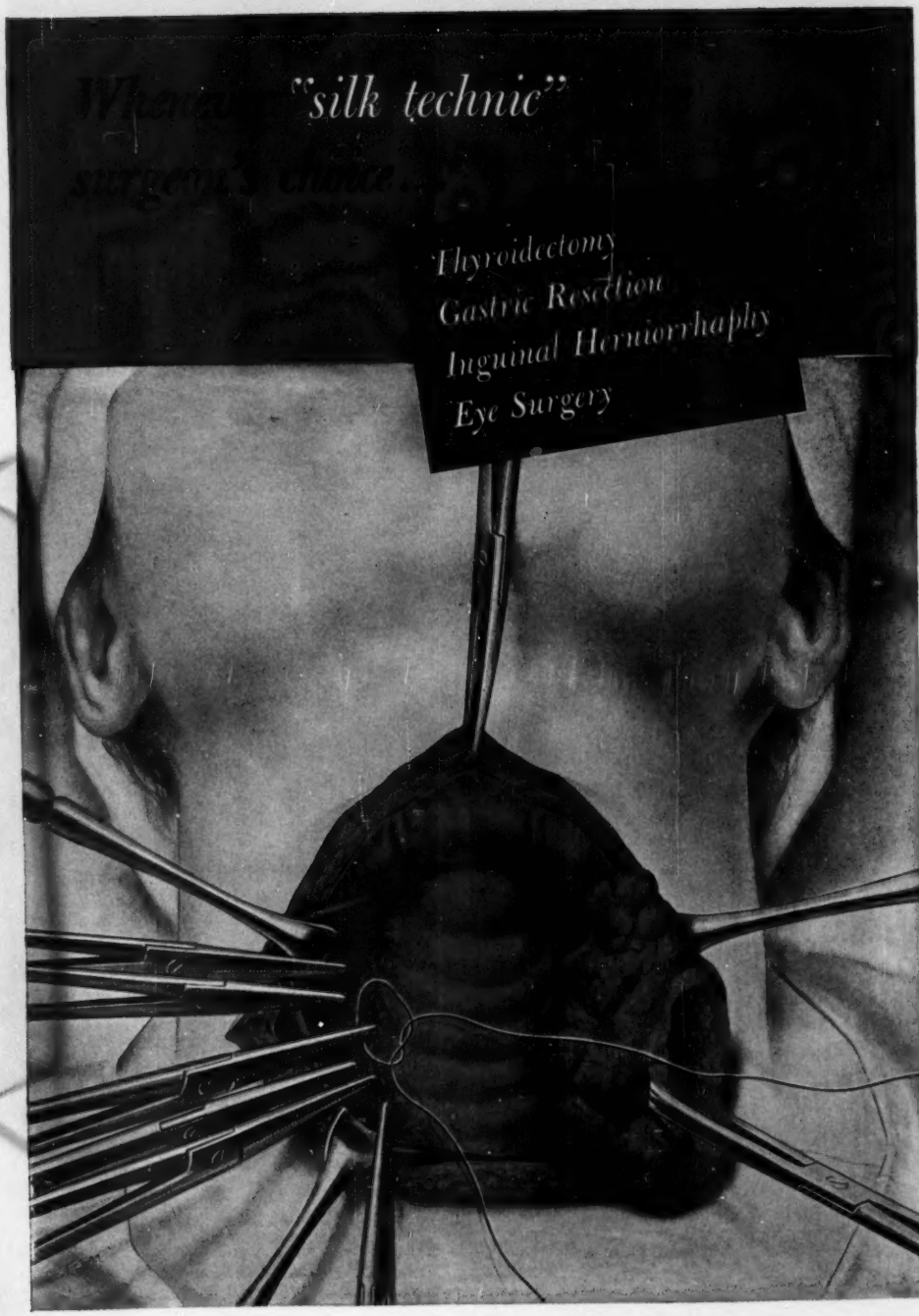
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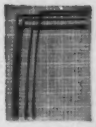

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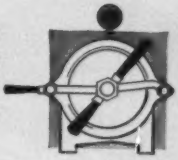

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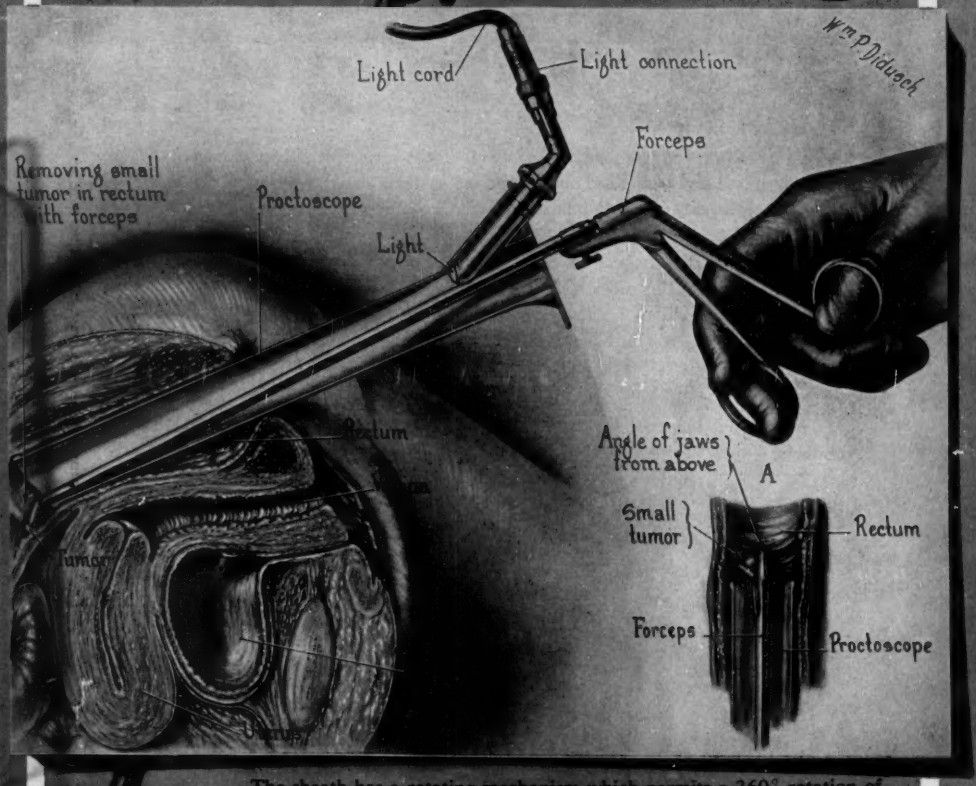

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LABORATORY AIDS IN SURGERY, WITH SPECIAL REFERENCE TO POTASSIUM DEFICIENCY

WARREN H. COLE, M.D.
CHICAGO

BY TRADITION, most of the presidents' addresses before this Society have been of a philosophical nature. However, being skeptical that I could utilize this principle and still maintain the high standard set by previous presidents, I have chosen to devote part of my time today to a scientific presentation.

VALUES AND PITFALLS OF LABORATORY AIDS IN SURGERY

Although a major portion of the progress made in surgery during the past half century has developed through physiologic and chemical mechanisms contained in laboratory tests and examinations, yet we have great difficulty in attaching the proper significance to this data. We must not fail to appreciate that laboratory tests can be of inestimable value in surgical diagnoses and indications for certain types of therapy, but they cannot be used effectively without the application of proper intelligence. Unless we use all our intellectual facilities in interpretation of laboratory data we are bound to make many serious errors in diagnosis and in judgment of therapy.

The basal metabolic rate is an example of a test which can be of great value in diagnosis yet may be exceedingly misleading. On perhaps 90 per cent of occasions it gives a fairly accurate estimate of the increase in metabolic rate even though there is a 10 per cent error, plus or minus, in the methods of performing the test. Of more significance is the fact that besides hyperthyroidism there are many diseases, such as pulmonary tuberculosis, polycythemia, leukemia and cardiac disease, in which the basal metabolic rate may be elevated 15 to 45 per cent above normal. Additional examinations such as blood counts will usually rule out such diseases as polycythemia and leukemia, and chest examinations (including x-ray studies) will exclude or identify most cases of pulmonary tuberculosis. Differentiation of cardiac disease from true hyperthyroidism is more difficult, particularly since a variable amount of cardiac insufficiency is present so often in hyperthyroidism (especially toxic nodular goiter).

The long used red blood count, hemoglobin and hematocrit determinations represent a source of serious error. In the first place, we must appreciate that in normal persons the red blood count may vary as much as 10 per cent during the day. However, this source of error is not so great as the dilution or concentration factor. For example, when a patient with partial intestinal obstruction is admitted to the ward he is invariably dehydrated because of vomiting and lack of intake. Accord-

Presidential address, read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

ingly, the red blood count, hematocrit and hemoglobin determinations will give falsely high readings. If this fact is not appreciated by the clinician, he may fail to give sufficient transfusions to the patient (with perhaps disastrous results), after a major operation.

The amylase test is a valuable indication of pancreatic disease yet may also be misleading. If this test is performed within six to eight hours after the onset of acute edematous pancreatitis, the reaction will be positive (i. e., readings above normal) in 80 to 90 per cent of cases. However, if the test is performed as long as 48 hours after onset of the disease, it will reveal normal or subnormal values in about the same percentage of cases, particularly if the clinical manifestations have receded in the meantime. In other words, the amylase test is one having value only if it reveals an elevated level. All those using the amylase test have encountered readings far below normal on numerous occasions. For a time we thought those low readings might have been an expression of hepatic insufficiency. However, I am now convinced that on the basis of clinical data this conclusion is not valid.

Sodium, potassium and chloride determinations are examples of tests in which values have a significance opposite to those indicated by amylase readings, i. e., they are of significance only if they are lower than normal, largely because administration of an excess of these ions does not result in an elevated level except perhaps as a terminal phenomenon. Often, indeed, the clinician is not certain as to how much of these ions should be given when a deficiency is present or when attempting to meet body needs in the absence of oral intake of food. Unfortunately, he must wait for the appearance of toxic manifestations before he knows too much has been given. In the case of potassium, he must look for cardiac damage with positive electrocardiographic findings; with sodium and chloride he must look for renal dysfunction, edema or similar disorders.

Liver function tests are examples of great variability in significance. It is well known that they are not particularly sensitive and, moreover, that one may give a positive reaction whereas another will give a negative reaction when performed at the same time. Accordingly, the clinician has learned that no single liver function test is reliable; often four or five must be performed before a significant interpretation can be made. Yet, these tests may be of tremendous value and prevent a serious error. For example, a patient admitted with massive hematemesis might have an ulcer or an esophageal varix as the source. It is essential to determine as soon as possible which lesion is the cause since the treatment is so different; in fact, erroneous therapy in this instance is apt to lead to a fatality. Splenomegaly and a history of ulcer will be of value in pointing to the diagnosis of portal hypertension and bleeding peptic ulcer, respectively, but it must be appreciated that in about one third of patients with massive hemorrhage from peptic ulcer there will be no definite history of ulcer and in almost an equal proportion of patients with portal hypertension there will be no splenomegaly. Portal hypertension is usually caused by cirrhosis or by an allied hepatic lesion, which can be detected on most occasions by liver function tests, providing more than one or two are utilized. Accordingly, liver function tests might add just enough data on a patient with hematemesis to make a correct diagnosis.

Laboratory tests are probably of greater aid to the surgeon in the preoperative preparation of the patient than in any other circumstance. Blood counts, urine

examination, nonprotein nitrogen and blood protein determinations are essential examinations if a major operation is contemplated. If the patient has been vomiting or has been on a low oral intake for several days, there may be a deficiency in electrolytes including, particularly, sodium, chloride and potassium. Fortunately, tests for these electrolytes are accurate when performed correctly. No major operation should be performed on any patient with vomiting or decreased oral intake without first obtaining data on the plasma level of these ions. It must be emphasized that the determination of sodium chloride as a single test is misleading; an accurate estimation of true values can be obtained only by a test for each ion individually.

In spite of the extreme value of laboratory tests to the surgeon, I hereby make a plea to economize on these tests because they require time for performance when ordered in excess and are a serious source of added unnecessary expense to the patient. In their endeavor to obtain a complete work-up on the patient, the house officer often orders such tests as creatinine and blood cholesterol determinations. It is just as much the obligation of the physician or surgeon in charge to control the enthusiasm of residents for unnecessary tests as it is to include the necessary ones. True enough, extreme intelligence is required in ordering just the right tests; yet that is a challenge we must meet and accept.

POTASSIUM DEFICIENCY

Although it has been only during the past few years that the importance of potassium deficiency has been appreciated, it is now well established that it alone may occasionally result in death. Much oftener its influence, added to that of two or three other complications, may be responsible for the death of the patient. Potassium deficiency [1] is present in surgical patients (particularly after operation) much oftener than is appreciated. For example, Snyder and Snyder [2] found levels of serum potassium below 3.8 milliequivalents per liter in nine of 30 patients after operation on the biliary tract and in eight of 42 patients having other types of operation. Among 38 consecutive major surgical cases, a potassium level of 3.8 milliequivalents or lower was found in 26; however, the authors considered that therapy was essential in only seven of the 26.

There are several factors responsible for the development of potassium deficiency. Important among these are lack of food intake, vomiting, gastrointestinal decompression, urinary excretion, fistulas and diarrhea. The pioneer work of Darrow,[3] showing a drop in the mortality rate for infantile diarrhea from 34 to 6 per cent obtained by giving potassium along with sodium chloride and sodium lactate, has exerted a major role in the appreciation of this condition.

Important Factors in Potassium Metabolism.—Although sodium has been considered by many to be present in the human body in quantities greater than any

1. In our laboratory the following values are considered normal: serum potassium, 4.1 to 5.6 milliequivalents; serum sodium, 138 to 148 milliequivalents; serum chloride (as NaCl), 570 to 620 mg. per 100 cc.; carbon dioxide-combining power, 55 to 75 volumes per cent; nonprotein nitrogen, 25 to 35 mg. per 100 cc.

2. Snyder, C. D., and Snyder, H. E.: Serum and Urinary Potassium in Surgical Patients, Arch. Surg. **61**:62 (July) 1950.

3. Darrow, D. C.: Congenital Alkalosis with Diarrhea, J. Pediat. **26**:519, 1945; The Retention of Electrolyte During Recovery from Severe Dehydration Due to Diarrhea, J. Pediat. **28**:515, 1946.

other cation, there is actually twice as much potassium as sodium in the body (Randall and his associates [4]). Potassium is present in intracellular fluid (e. g., muscle, liver), whereas sodium is present in plasma and the extracellular fluid; about 98 per cent of potassium is found in the intracellular fluid. It is now appreciated that in dehydration and many conditions leading to salt loss, some of the cell potassium may be transferred to the extracellular space and be replaced by sodium from the plasma or interstitial fluids.

Unlike sodium, potassium is excreted by the kidney during an existing deficiency; for this reason it can be seen that the clinician receives little help from the patient's body in the correction of a deficiency. In a series of patients with hypopotassemia studied by Marks,[5] he noted that 15 to 36 mEq. of potassium was lost in the urine daily. Massive infusions of saline or glucose are important factors in potassium loss; sodium replaces potassium in this process, giving rise to edema. Losses may be large in dehydration because the kidney preferentially secretes potassium instead of sodium.

In starvation, potassium losses may be considerable; in fact, years ago, Benedict [6] showed that 2.87 milliequivalents of potassium is lost with each gram of nitrogen. Potassium losses after major operations are large and are greatest during the first 24 hour period, partly because of the high nitrogen loss during this period. Adrenal cortical hormones likewise increase potassium excretion.

Alkalosis is an important accompaniment of potassium deficiency but occasionally is absent; not infrequently the alkalosis is the cause of the potassium deficiency. Alkalosis is refractory to sodium chloride therapy if potassium deficiency persists. Evans [7] has remarked that if an alkalosis with a carbon dioxide volume above 60 per cent persists in patients with vomiting, after adequate hydration and sodium chloride therapy, a potassium deficiency should be suspected. It is now likewise appreciated that hypochloremic alkalosis is an indication of potassium deficiency.

Randall and his associates [4] have conducted detailed experiments on the content of various body secretions and fluids. For example, on the average their analyses revealed the gastric content to contain 9.2 milliequivalents of potassium per liter, bile to contain 4.98, pancreatic juice 4.6 and urine 20 to 60 milliequivalents (1 Gm. potassium, 25.6 mEq). They also noted that the average daily loss of potassium in patients on intravenous fluids was in the neighborhood of 30 milliequivalents.

Clinical Manifestations of Potassium Deficiency.—Unfortunately, there is no consistency in the symptomatology of potassium deficiency; in fact, there is no single symptom which can be considered strongly indicative of the condition. The two most dependable mechanisms of confirming the condition are (1) electrocardiographic tracings (low amplitude of T waves and lengthening of the Q-T interval) and (2) serum potassium determinations. Alkalosis is fairly constant but obviously may be caused by many other conditions. We have now had enough experience

4. Randall, H. T.; Habif, D. V.; Lockwood, J. S., and Werner, S. C.: Potassium Deficiency in Surgical Patients, Surgery **26**:341, 1949.

5. Marks, L. J.: Potassium Deficiency in Surgical Patients, Ann. Surg. **132**:20, 1950.

6. Benedict, F. G.: A Study of Prolonged Fasting, Publication 203, Carnegie Institution of Washington, 1915.

7. Evans, E. I.: Potassium Deficiency in Surgical Patients: Its Recognition and Management, Ann. Surg. **131**:945, 1950.

with the condition to know that any patient who has had a major abdominal operation, and at least three full days of gastrointestinal decompression, is likely to have a potassium deficiency.

Perhaps the commonest symptom is weakness, but it was not present in at least two of 12 patients with the condition observed in the past two years in our clinic. Anorexia is common, but nausea and vomiting are less so. Restlessness, apprehension and diffuse pains, particularly abdominal, are likewise common but are so frequently observed in the postoperative course of patients with major abdominal operations that they cannot be definitely ascribed to the potassium deficiency. Several of our patients complained of inability to sleep. Abdominal distention and peripheral edema have been listed by other observers as occurring in potassium deficiency, but they have not been at all prominent in our patients. Difficulty in talking and breathing are also listed by other observers as being encountered occasionally, but we have not observed either. Many of our patients have been drowsy and semistuporous; one of them was completely irrational. An increase of the nonprotein nitrogen has been observed in many of our cases. We doubt that this condition can be considered distinctly secondary to potassium deficiency, since it is also seen in chloride deficiency. Nevertheless, it has been common in our cases and in one or two without chloride deficiency. However, there is one consistent feature about the symptoms, namely, that they disappear rapidly after the patient begins to eat and retain food; likewise, the serum potassium level reverts to normal rapidly after eating is resumed.

Treatment of Potassium Deficiency.—The most acceptable drug for the treatment of potassium deficiency is potassium chloride; it may be given orally or intravenously. With a patient under gastric decompression after a major celiotomy, 3 Gm. in 24 hours is not sufficient to restore the potassium level or even to exert a significantly favorable effect on it. In the same circumstances a dose of 6 Gm. per day is sufficient to elevate the depleted potassium level to a certain extent; the degree of improvement is dependent on certain circumstances, particularly the amount of fluid lost by gastric suction or urinary output. For example, in one of our patients under gastric decompression after celiotomy, the depletion was corrected with 6 Gm. of potassium chloride per day, whereas in another it remained apparently unchanged. In the former patient (see chart 4), in whom the level was brought back to normal with 6 Gm. before eating was resumed, the average daily loss from gastric decompression and urinary excretion was 2,890 cc. In the latter patient (see chart 3), in whom the level was not brought back to normal with 6 Gm. daily, the average daily output was 3,245 cc., approximately 350 cc. more. There might be a temptation to conclude that this amount was sufficient to make the difference between the return to normal and failure in improvement; however, there are unquestionably many factors, such as concentration of potassium in the decompression fluid, urine, etc., which exert a more important role than the difference of 350 cc. in daily output.

There is considerable difference of opinion concerning the methods of administration and types of solution recommended by the various workers in this field. An isotonic solution (1.14 Gm. of potassium chloride per 100 cc. of water) is a convenient solution (Bellet) but is more concentrated than need be. We have found it much more convenient to keep the solution in a sterile bottle in the hospital ward

(in a concentrated form, e.g., 30 per cent) and add the desired amount to the intravenous fluids, such as 5 per cent glucose [7a] or 5 per cent amino acid (amigen®) with 5 per cent glucose. In our estimation the safest solution would appear to be the addition of 2 to 4 Gm. of potassium chloride to 1,000 cc. of 5 per cent glucose. In the presence of severe deficiency, 4 Gm. may safely be given in two or three hours and repeated a short time later, if urinary excretion is unimpaired. After the depletion is largely corrected the solution should be given more slowly; this may be accomplished by adding 2 Gm. to each of 2 liters of glucose, assuming that a total of about 4 Gm. per day will be needed to maintain a satisfactory level once it is achieved.

Administration of potassium is dangerous in acute or chronic renal disease. It should not be given in the presence of dehydration until enough fluid has been given to restore urinary secretion; likewise it is unsafe in the first 24 hours following a major operation because urinary secretion is so limited during this period.

If the status of the secretory function of the kidney is unknown, several hundred cubic centimeters of 5 per cent glucose should be given to stimulate urine flow. It is always wise to have a plasma determination available before starting potassium therapy because rapid administration is much safer if depletion is considerable. In case of doubt as to the rapidity and amount of administration, serial electrocardiographic tracings should be obtained. Once the serum carbon dioxide level has fallen to normal, it may be assumed that the potassium depletion is no longer significant.

It must be appreciated that occasionally potassium depletion may exist in the presence of normal or near normal levels (Evans).[7] The indication of depletion in such a circumstance may be found in the presence of alkalosis after ample water and sodium chloride have been given.

CASE 1.—The patient was a white man aged 71 who underwent an abdominoperineal resection in December 1948 for a carcinoma of the rectum. On May 25 he received a barium enema through the colostomy opening in an attempt to find the source of slight bleeding from the colostomy opening on two or three occasions. During expulsion of the barium he experienced severe pain in the abdomen. A roentgenogram revealed a large amount of air and barium in the peritoneal cavity outside the intestine. A perforation of the intestine was obvious. At operation, a perforation of the sigmoid 3 inches (7.6 cm.) proximal to the colostomy was found. The sigmoid was mobilized and enough brought out through the wound to excise the segment including the perforation. The patient's course was as follows:

May 25 (see chart 1)
Operation for perforation of the sigmoid, 9:00 p. m.
1,500 cc. blood; 500 cc. saline
Gastrointestinal suction, 400 cc; urine, 450 cc.

May 26 (first postoperative day)
Carbon dioxide, 50 volumes per cent
3,000 cc. 5 per cent glucose;
Gastrointestinal suction, 400 cc.; urine, 900 cc.

May 27 (second postoperative day)
1,000 cc. 5 per cent glucose with saline; 2,000 cc. amigen®
Gastrointestinal suction, 500 cc.; urine, 1,650 cc.

May 28 (third postoperative day)
1,000 cc. 5 per cent glucose; 3,000 cc. amigen®
Slight irregularity of pulse
Gastric tube removed; urine, 1,200 cc.

7a. When glucose is referred to in this article *d*-glucose was used.

May 29 (fourth postoperative day)

1,000 cc. 5 per cent glucose; 2,000 cc. amigen®

Restless and apprehensive; slept poorly last night, vomited small quantity; gastric tube reinserted

Gastrointestinal suction, 750 cc.; urine, 700 cc.

May 30 (fifth postoperative day)

Nonprotein nitrogen, 46 mg.; carbon dioxide, 60 volumes per cent; serum chloride, 528 mg.

Apprehensive, slept poorly last night

Complaining of diffuse pain; confused and irrational

1,000 cc. 5 per cent glucose with saline; 2,000 cc. amigen®

Large amount (1,000 cc.) dark green liquid from colostomy

Gastrointestinal suction tube removed but reinserted later because of vomiting

Gastrointestinal suction, 610 cc.; urine, 950 cc.

May 31 (sixth postoperative day)

1,000 cc. amigen®; 1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride

Large amount (750 cc.) dark green liquid from colostomy

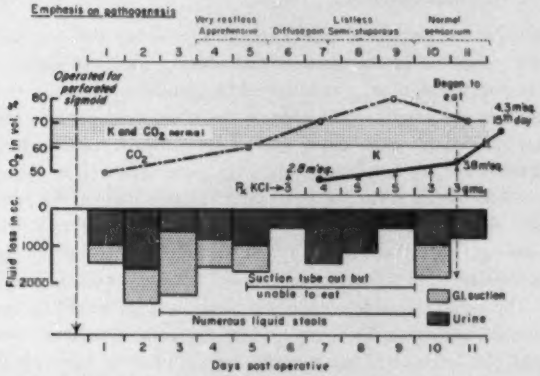

Chart 1.—Potassium deficiency after repair of perforated sigmoid. Although the amount of fluid lost by decompression in this case was relatively small, the numerous liquid stools and inability to eat are sufficient to account for development of the deficiency.

Pulse irregular

Gastrointestinal suction tube removed; urine, 400 cc.

June 1 (seventh postoperative day)

Serum potassium, 2.8 mEq.; sodium, 132 mEq.; carbon dioxide, 71 volumes per cent; nonprotein nitrogen, 45 mg.

2,000 cc. amigen®; 1,000 cc. 5 per cent glucose with 4 Gm. potassium chloride

Complaining of severe diffuse pain; restless; slightly stuporous

Taking small amount of liquid diet by mouth

Electrocardiographic tracing indicative of hypopotassemia

Urine, 1,400 cc.

June 2 (eighth postoperative day)

Listless, almost stuporous

1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride; 2 Gm. potassium chloride by mouth

About 700 cc. liquid stool from colostomy

Urine, 1,150 cc.

June 3 (ninth postoperative day)
Carbon dioxide, 80 volumes per cent; serum chloride, 521 mg.
Less confused; more cheerful
1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride; 2 Gm. potassium chloride by mouth
Emergency operation for wound dehiscence
Urine, 550 cc.

June 4 (tenth postoperative day)
2,000 cc. 5 per cent glucose; 2,000 cc. amigen®; 3 Gm. potassium chloride
Gastrointestinal suction, 840 cc.; urine, 975 cc.

June 5 (eleventh postoperative day)
Potassium, 3.8 mEq.; carbon dioxide, 72 volumes per cent; serum chloride, 520 mg.; 1,000 cc. saline with 3.0 Gm. potassium chloride
Urine, 750 cc.

From June 5 on, the patient began to eat and his improvement was gradual and progressive. On the fifteenth postoperative day (June 9) the potassium level was 4.3 milliequivalents and the carbon dioxide-combining power 62 volumes per cent. The sodium content of the serum remained normal (134 milliequivalents).

Comment.—In this patient it was necessary to delay the oral intake of food postoperatively; removal of the suction tube during the first eight postoperative days for the perforated sigmoid was followed by vomiting, which, in retrospect, was probably related to the wound dehiscence on the ninth postoperative day. The lack of oral intake of food for nine days, loss of intestinal secretions by suction and numerous liquid stools are ample to explain the potassium deficiency, in the face of the administration of only 7 Gm. of potassium chloride during the first seven postoperative days. The serum potassium level of 2.8 milliequivalents at the end of this period (i. e., seventh postoperative day) is obvious proof that our potassium therapy had been inadequate. The electrocardiographic tracings were indicative of hypopotassemia. The carbon dioxide-combining power was increased during the period of hypopotassemia, returning to normal when the potassium level became normal or near normal. In retrospect, our therapy with potassium, consisting of administration of 3 to 5 Gm. per day to this patient during his deficiency, was entirely inadequate. Restoration of the serum potassium to normal was accomplished largely through oral intake of food, which was not tolerated by the patient until the eleventh postoperative day.

Case 2.—The patient was a white woman aged 59 who entered Illinois Research Hospital on April 27, 1950, complaining of pain in the right upper quadrant and jaundice. Since 1941 she had occasional attacks of pain in the right upper quadrant associated with fat intolerance. In February 1949 she noted onset of jaundice with an attack of pain. The jaundice lasted three months, after which time the pain disappeared. In February 1950 she had a similar attack accompanied with nausea but no vomiting; jaundice lasted eight weeks in this attack. Cholecystography revealed normal concentrating power of the gallbladder, but stones were present within it.

On May 9, 1950, celiotomy was performed. A gallbladder containing stones was removed. The common duct was about normal size; no stones were palpable within it, but it was opened. No stones could be found in the duct, but a probe could not be passed through the ampulla of Vater. Accordingly, a longitudinal incision was made in the duodenum. A probe was finally passed through the ampulla, but with difficulty because of induration in the head of the pancreas. The incision in the duodenum was closed transversely and a T tube sutured in place within the common duct. The patient's course was as follows:

May 9, 1950 (see chart 2)
Cholecystectomy and choledochostomy
500 cc. saline; 500 cc. blood; 200 cc. 5 per cent glucose
Gastrointestinal suction, 600 cc., bile from T tube, 55 cc.; urine, 625 cc.

May 10, 1950 (first postoperative day)
Nonprotein nitrogen, 25 mg. per 100 cc.; carbon dioxide, 57 volumes per cent
1,000 cc. 5 per cent glucose; 2,000 cc. amigen®
Complaining of slight vertigo
Gastrointestinal suction, 600 cc.; bile from T tube, 50 cc.; urine, 1,900 cc.

May 11, 1950 (second postoperative day)
1,000 cc. 5 per cent glucose; 2,000 cc. of amigen®
Gastrointestinal suction, 750 cc.; bile, 100 cc.; urine, 1,100 cc.

May 12, 1950 (third postoperative day)
Potassium, 2.9 mEq.; nonprotein nitrogen, 31 mg. per 100 cc.; sodium, 141 mEq.; carbon dioxide, 53 volumes per cent

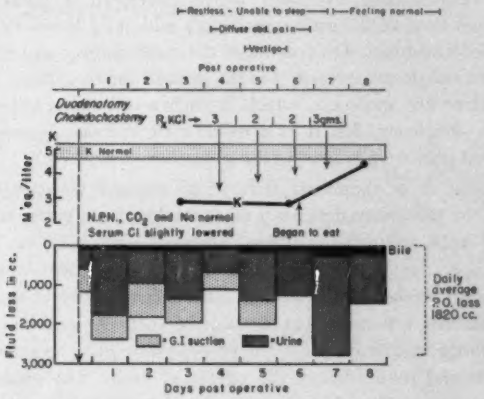

Chart 2.—Potassium deficiency following choledochostomy. In this patient, who had undergone a choledochostomy, gastrointestinal decompression was maintained for five days postoperatively because the papilla of Vater was exposed by a duodenostomy and its closure appeared to constrict the intestinal lumen slightly.

1,000 cc. 5 per cent glucose; 2,000 cc. amigen®
Slept well last night but complaining of diffuse abdominal pain
Gastrointestinal suction, 400 cc.; bile, 100 cc.; urine, 1,625 cc.

May 13 (fourth postoperative day)
Nonprotein nitrogen, 38 mg.; carbon dioxide, 64 volumes per cent; serum chloride, 538 mg.
1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride
2,000 cc. amigen®
Gastrointestinal suction, 400 cc.; bile, 50 cc.; urine, 700 cc.

May 14 (fifth postoperative day)
2,000 cc. amigen®; 1,000 cc. 5 per cent glucose with 2 Gm. potassium chloride
Slept poorly last night; slight vertigo
Complaining of feeling "bad all over"
Gastrointestinal suction, 400 cc.; bile, 100 cc.; urine, 1,450 cc.
Suction tube removed

May 15 (sixth postoperative day)
Potassium, 2.8 mEq.; nonprotein nitrogen, 31 mg.; sodium, 138 mEq.; carbon dioxide, 65 volumes per cent; serum chloride, 556 mg.
1,000 cc. 5 per cent glucose; 2,000 cc. aminosol®; 2 Gm. potassium chloride
Slept very poorly last night; uncomfortable
Began eating soft diet, very small amount
Bile, 50 cc.; urine, 1,250 cc.

May 16 (seventh postoperative day)
Eating soft diet; slept poorly last night but comfortable now
3 Gm. potassium chloride by mouth
Bile, 300 cc.; urine, 2,700 cc.

May 17 (eighth postoperative day)
Potassium, 4.3 mEq.; nonprotein nitrogen, 27 mg.; sodium, 136 mEq.; carbon dioxide, 59 volumes per cent; serum chloride, 531 mg.
Urine, 1,500 cc.
Feeling about normal

Comment.—The patient discussed above developed a potassium deficiency (serum potassium level of 2.9 milliequivalents) within 72 hours following duodenotomy and choledochostomy. On account of the duodenotomy and diffuse abdominal pain, gastrointestinal decompression was maintained for five days. The patient did not complain of severe weakness, which is such a common complaint of patients with potassium deficiency, but it is possible that the sleeplessness, vertigo and diffuse abdominal pain were related to the potassium deficiency.

In this patient it is somewhat difficult to explain the comparatively rapid development of the potassium deficiency since the loss from gastrointestinal suction, bile from the T tube and urine combined averaged only 2,208 cc. for each of the first three postoperative days. Nevertheless, since the patient was comparatively healthy for several weeks just preceding operation, it must be assumed that the serum potassium level was normal at the time of operation and had dropped to the level of 2.9 milliequivalents on the third postoperative day because of loss of this amount of fluids and the effects of the operation itself. The intake of potassium chloride was not forced beyond 3 Gm. per day, largely because the patient began to eat satisfactorily shortly after we discovered the hypopotassemia. However, for the few days she was observed under hypopotassemia (during which time she ate nothing) the serum level did not show any upward trend, indicating that 2 or 3 Gm. of potassium chloride is not adequate to improve potassium deficiency in a patient under gastric decompression.

CASE 3.—The patient was a white man aged 52 years who entered Illinois Research Hospital on April 25, 1950, complaining of abdominal pain, nausea and vomiting. The present illness started 28 years previously with typical ulcer symptoms relieved by food and alkali; however, the patient had had intervals of freedom from symptoms. In February 1948 he underwent a cholecystectomy and in October 1948 a gastrectomy. He was free from symptoms for six months, after which time epigastric pain, not relieved by food or alkali, developed. During the past 12 months since development of these symptoms the patient had vomited blood once and had several tarry stools. A series of gastrointestinal roentgenograms revealed a marginal ulcer. On May 5, 1950, the patient underwent a celiotomy; a marginal ulcer perforating against the liver was found. A vagotomy was considered, but in view of the edema about the cardia it was decided to do it later through a transthoracic approach. On May 13 the patient was subjected to an emergency closure of a wound separation. Before repair of the wound separation and for several days thereafter gastric decompression was necessary most of the time because

of anorexia and vomiting. On May 25 (12 days after repair of the wound dehiscence) and May 26 the serum potassium level was 2.8 milliequivalents; the serum sodium chloride was slightly depressed (446 mg. per 100 cc.). Accordingly, on May 25 and for five days thereafter, the patient was given 3 Gm. of potassium chloride and 6 Gm. of ammonium chloride daily. This therapy brought the potassium level up to 4.0 and the serum sodium chloride back to near normal. During this period the carbon dioxide-combining power was sharply increased, the highest level being 104 volumes per cent. After the restoration of electrolytic imbalance the patient convalesced satisfactorily, but evidence of obstruction at the stoma developed. Accordingly, it was decided to perform a gastrectomy (excising the gastrojejunal ulcer) and not a vagotomy. The patient's course was as follows:

June 15, 1950 (see chart 3)
Subtotal gastrectomy
500 cc. saline, 1,000 cc. 5 per cent glucose, 2,000 cc. blood
Gastrointestinal suction, 800 cc.; urine, 200 cc.

June 16, 1950 (first postoperative day)
Potassium, 3.5 mEq.; nonprotein nitrogen, 72 mg. per 100 cc.; carbon dioxide, 72 volumes per cent; serum sodium chloride, 449 mg. per 100 cc.

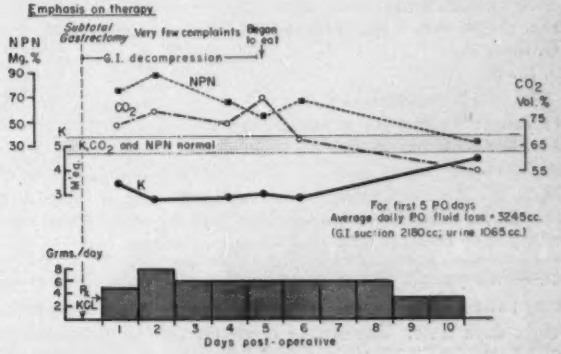

Chart 3.—Potassium deficiency following gastrectomy. Gastrectomy, with removal of a gastrojejunal stoma and ulcer was performed on this patient. A dose of 6 Gm. of potassium chloride per day was not sufficient to relieve the potassium deficiency, partly because of the fact that the average daily fluid loss (urine and suction) was unusually large, namely 3,245 cc. The deficiency was relieved only when the patient began to eat. (Contrast with response of patient in chart 4.)

1,000 cc. 5 per cent glucose; 2,000 cc. amigen®
1,000 cc. 5 per cent glucose in saline with 5 Gm. potassium chloride
Gastrointestinal suction, 1,500 cc.; urine, 550 cc.

June 17, 1950 (second postoperative day)
Potassium, 2.9 mEq.; nonprotein nitrogen, 86 mg.; carbon dioxide, 79 volumes per cent; serum sodium chloride, 482 mg.
1,000 cc. 5 per cent glucose; 1,000 cc. amigen® with 5 Gm. potassium chloride
500 cc. feeding through Abbott-Rawson tube with 3 Gm. potassium chloride
Gastrointestinal suction, 2,350 cc.; urine, 675 cc.

June 18, 1950 (third postoperative day)
1,000 cc. glucose; 2,000 cc. amigen®
1,000 cc. feeding through Abbott-Rawson tube with 6 Gm. potassium chloride and 6 Gm. ammonium chloride
Gastrointestinal suction, 2,900 cc.; urine 1,750 cc.

June 19, 1950 (fourth postoperative day)
Potassium, 2.9 mEq.; nonprotein nitrogen, 63 mg.; carbon dioxide, 74 volumes per cent; serum chloride, normal
2,000 cc. 5 per cent glucose; 2,000 cc. amigen® with 6 Gm. potassium chloride
Gastrointestinal suction, 3,400 cc.; urine, 2,200 cc.

June 20, 1950 (fifth postoperative day)
Potassium, 3.0 mEq., nonprotein nitrogen, 51 mg.; carbon dioxide, 83 volumes per cent
1,000 cc. 5 per cent glucose; 1,000 cc. 10 per cent glucose; 2,000 cc. amigen® with 6 Gm. potassium chloride
Gastrointestinal suction, 1,800 cc.; urine, 1,350 cc.
R. A. tube removed

June 21, 1950 (sixth postoperative day)
Potassium, 2.9 mEq.; nonprotein nitrogen, 45 mg.; carbon dioxide, 77 volumes per cent
1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride; 2,000 cc. amigen® with 3 Gm. potassium chloride
800 cc. liquid diet
Urine, 1,000 cc.

June 22, 1950 (seventh postoperative day)
1,000 cc. glucose with 6 Gm. potassium chloride; 2,000 cc. amigen®
400 cc. liquid diet
Urine, 525 cc.

June 23, 1950 (eighth postoperative day)
2,000 cc. amigen® with 6 Gm. potassium chloride
1,400 cc. liquid diet
Urine, 450 cc.

On June 24, 25 and 26 the oral intake was increased, but 3 Gm. of potassium chloride were given each day. On June 26 (eleventh postoperative day) the serum potassium was 4.3 milliequivalents and all other chemical readings likewise were normal.

Comment.—This patient with a gastrojejunal ulcer had two periods of potassium deficiency; the first occurred after a celiotomy (exploratory) and a wound dehiscence eight days later. The second occurred after a gastrectomy which was performed five weeks after repair of the wound separation. The cause of the deficiency in each instance was high fluid output (gastrointestinal decompression and urine excretion), along with a delayed oral intake of food. Food intake was delayed because of anorexia and vomiting. In each of these attacks the patient had few symptoms related to the deficiency. Six grams of potassium chloride were given daily in each attack to restore the level to normal; with this dose, improvement in the potassium was really shown only after the patient began eating. The serum carbon dioxide and nonprotein nitrogen levels were distinctly increased and returned to normal as the low potassium levels came back up to normal. Since there was no demonstrable kidney damage in this patient, the potassium and chloride deficiency may be suspected as exerting a prominent role in the increase of the nonprotein nitrogen. The sodium levels were normal; serum chloride levels were slightly depressed during each attack (lowest, 432 mg. per 100 cc.). Ammonium chloride was given orally or intravenously during each attack in amounts varying between 3 and 6 Gm. per day.

Case 4.—The patient, a white man aged 83, was admitted to the Illinois Research Hospital on May 19, 1950, complaining of loss of 15 pounds (6.8 Kg.) in weight during the past eight months. During this time he had been nauseated but had no vomiting. There was no

significant abdominal pain. For the past six months he had some poorly localized pain in the arms and shoulders. Three weeks previously he had noted a mass in the abdomen. Close questioning revealed a history of blood in the stool for two days about a year previously. He had no change in bowel habits, nor had he noticed any blood in his stool since the one previous attack. Physical examination revealed an elderly man in a fair state of preservation for his age. There was a mass 11 by 7 cm. just above and slightly to the left of the umbilicus. This mass was nodular and firm. It was freely movable and not tender. The blood pressure was 180/90.

After routine preparation, celiotomy was performed on May 29, 1950. A large carcinoma in the transverse colon was found. No metastases were noted. Accordingly, an obstructive resection was performed, with a double-barreled colostomy in view of the patient's age. The postoperative course was as follows:

May 29, 1950

Resection of colon by obstructive resection technic with double-barreled colostomy

1,900 cc. 5 per cent glucose; 300 cc. saline; 1,000 cc. blood

Gastrointestinal suction, 100 cc.; urine output, 300 cc.

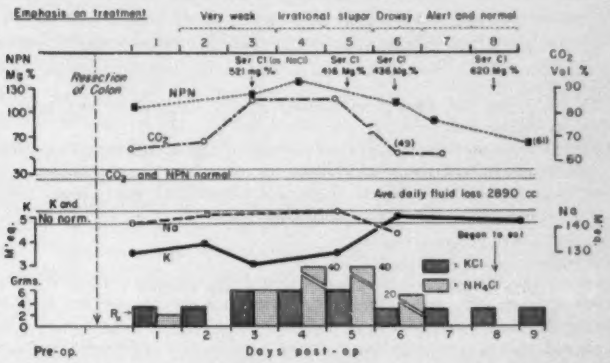

Chart 4.—Potassium deficiency following resection of colon. In this patient, who had undergone a resection of the colon for carcinoma, the potassium level was found to be 3.5 milliequivalents (lower limits of normal) on the day following operation. However, it was not until about the third postoperative day that it was definitely low (2.9) milliequivalents and significant symptoms appeared. Note the inverse correlation of the carbon dioxide and potassium levels. In this patient 6 Gm. of potassium chloride was sufficient to correct the deficiency before the patient began to eat, even though the average daily fluid loss from gastric decompression, urine and liquid stools was 2,890 cc.

May 30, 1950 (first postoperative day)

2,000 cc. 5 per cent glucose with 200 cc. 50 per cent glucose

1,000 cc. amigen®

Given 9.6 Gm. vitamin K on basis of bleeding from prothrombin deficiency

Had cardiac irregularity, for which digitalis was given

Gastrointestinal suction, 2,700 cc. "coffee ground" material; urine, 700 cc.

May 31, 1950 (second postoperative day)

Very weak and listless

Potassium, 3.5 mEq.; nonprotein nitrogen, 104 mg.; serum chloride (as NaCl), 541 mg. per 100 cc.

Carbon dioxide, 65 volumes per cent; sodium, 141 mEq.

1,000 cc. 2 per cent ammonium chloride with 3 Gm. potassium chloride; 1,000 cc. saline

2,000 cc. 5 per cent glucose with 100 cc. 50 per cent glucose; 1,600 cc. amigen®

Gastrointestinal suction tube removed last night but vomited 1,700 cc. and 1,000 cc. more obtained by tube rest of day

Given 9.6 mg. vitamin K; urine output, 500 cc.

June 1, 1950 (third postoperative day)
Potassium, 3.6 mEq.; nonprotein nitrogen, 132 mg.; carbon dioxide, 67 volumes per cent; sodium, 143 mg.; serum chloride, 521 mg.
1,000 cc. amigen® with 3 Gm. potassium chloride; 1,000 cc. 5 per cent glucose
1,000 cc. blood; 4.8 mg. vitamin K
Very listless and weak; 300 to 500 cc. dark brown liquid material from colostomy
Electrocardiogram indeterminate for K deficiency because of digitalis
Gastrointestinal suction, 1,400 cc.; urine output, 700 cc.

June 2, 1950 (fourth postoperative day)
Potassium, 2.9 mEq.; nonprotein nitrogen, 126 mg.; carbon dioxide, 96 volumes per cent; serum chloride, 416 mg.
1,000 cc. amigen®; 1,000 cc. 5 per cent glucose with 2 Gm. potassium chloride
2,000 cc. 2 per cent ammonium chloride with 4 Gm. potassium chloride; 4.8 mg. vitamin K
Irrational
Gastrointestinal suction, 2,400 cc.; about 1,000 cc. dark brown liquid fecal material from colostomy; urine output, 1,250 cc.

June 3, 1950 (fifth postoperative day)
Nonprotein nitrogen, 138 mg.; carbon dioxide, 96 volumes per cent; serum chloride, 436 mg.
Stuporous; irrational
1,000 cc. 2 per cent ammonium chloride with 2 Gm. potassium chloride; 2,000 cc. 10 per cent glucose
1,000 cc. 2 per cent ammonium chloride with 4 Gm. potassium chloride, but ran subcutaneously in both legs
Gastrointestinal suction, 750 cc.; 1,200 to 1,500 cc. dark brown liquid fecal material from colostomy; urine output, 1,375 cc.

June 4, 1950 (sixth postoperative day)
Still stuporous and irrational
1,000 cc. 2 per cent ammonium chloride with 4 Gm. potassium chloride
1,000 cc. 5 per cent glucose with 2 Gm. potassium chloride
500 cc. blood; 4.8 mg. vitamin K
Pain and redness over both legs at site of extravasation of intravenous fluids
800 to 1,000 cc. dark brown liquid fecal material from colostomy; gastrointestinal suction, 1,050 cc.; urine output, 1,550 cc.

June 5, 1950 (seventh postoperative day)
Potassium, 4.9 mEq.; nonprotein nitrogen, 113 mg.; carbon dioxide, 49 volumes per cent; serum chloride, 630 mg.
Drowsy but not irrational
1,000 cc. aminosol®; 1,000 cc. 10 per cent glucose
1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride; 4.8 mg. vitamin K
800 to 1,000 cc. dark brown fecal material from colostomy
Gastrointestinal suction, 700 cc. (tube removed); urine, 1,950 cc.

June 6, 1950 (eighth postoperative day)
Nonprotein nitrogen, 93 mg.; carbon dioxide, 48 volumes per cent, serum chloride, 639 mg.
Alert; normal sensorium
1,000 cc. 5 per cent glucose with 3 Gm. potassium chloride
Eating small quantity of food
Still profuse brown-black drainage from colostomy; urine, 1,400 cc.

Comment.—Within 48 hours after operation this patient had a serum potassium level of 3.5 milliequivalents and had one of the important symptoms of potassium deficiency, namely, extreme weakness. Three grams of potassium chloride were given on the second postoperative day and 6 Gm. on the third. On the morning of

the fourth postoperative day, the serum potassium was down to 2.9 milliequivalents and the patient was slightly irrational (see chart 4). By the next day he was distinctly irrational and stuporous. To overcome the potassium deficiency it was necessary to give 6 Gm. of potassium chloride daily for three days. Because of nausea and vomiting, gastrointestinal decompression was necessary in this patient for seven days. Perusal of the fluid intake and urinary output would indicate that we had perhaps given the patient more fluid than he needed, although the urinary output during his critical period averaged only 1,380 cc. This excess fluid (although only slight) no doubt increased the potassium deficiency because of increased urinary excretion of potassium. However, the high fluid intake was maintained largely because there was such a significant increase in the nonprotein nitrogen, which, however, developed in spite of apparently normal kidneys.

The sodium level remained normal at all times, but the serum chloride was very low for several days postoperatively. Accordingly, massive doses of ammonium chloride were given; 40 Gm. were given on each of the fourth and fifth postoperative days in a 2 per cent solution intravenously. This brought the serum chloride up only to 436 mg. per 100 cc., but with additional therapy (20 Gm. on the sixth postoperative day), it came up to normal. In view of a normal level of plasma sodium, the amount of sodium chloride given (in amigen,* blood and saline solution) was kept down to an average of 4 Gm. per day or slightly less, because of a possible "overload" on the kidney.

It is difficult to explain the irrationality and stupor on the basis of one single factor. In this patient it appears that two or three factors may have exerted a role; the increased nonprotein nitrogen and decreased serum potassium were probably the primary factors. Of these two, it is difficult to discern which may have been more important. It would appear that the increased nonprotein nitrogen was by no means the most important factor, because the stupor and irrationality disappeared as the potassium level was restored to normal and before a significant drop in the elevated nonprotein nitrogen level took place. It is perhaps just as difficult to explain the elevated nonprotein nitrogen level. Presumably it was caused by the chloride and potassium depletion. Certainly it was not due to dehydration (in face of a urinary output of 1,360 cc. per day); there were no urinary findings to indicate that kidney damage exerted a significant role.

The danger of intravenous administration of concentrated (and hypertonic) solutions is illustrated in this patient. It became obvious that administration of 3 Gm. of potassium chloride per day was inadequate to restore the potassium level to normal. In our efforts to maintain potassium balance, on two occasions 1,000 cc. of 2 per cent ammonium chloride containing 4 Gm. of potassium chloride were given. Extravasation occurred, and the skin over each leg at the site of injection (intravenous) became gangrenous; the area measured at least 5 by 10 cm. on each side. A skin graft was necessary on each side. The needle may have become dislodged on each side. However, I believe it is more likely that the vein receiving the solution became obstructed by edema and spasm, thus allowing the solution to reflux out of the vein into the subcutaneous tissue under the skin.

SUMMARY

The introduction of an increasing number of laboratory tests and improvements made in many others during the past 15 or 20 years has led to a much greater

accuracy in the diagnosis of surgical lesions. However, since few tests are infallible, it follows that blind acceptance of these tests would lead to a great number of diagnostic errors. To prevent such errors the clinician must be astute in interpretation of results and learn when to ignore the laboratory test and rely on his clinical judgment. The house officers in our hospitals have learned the great value of these tests, and often, to please their chief, they order laboratory tests in great numbers. Many of these will be of little or no value in the diagnosis but add greatly to the cost of hospital care. It is the responsibility of the attending physicians to guard against this abuse and protect the patient against increasing costs as well as conserve the time and energy of technicians on needless work. We must accept this responsibility.

One of the important surgical complications clarified by recent advances in biochemistry is hypopotassemia. Although this condition alone is responsible for the death of comparatively few patients, there is no doubt that when it is associated with other complications it may be an associated factor in a great many deaths. Hypopotassemia is found primarily in patients who have gastrointestinal decompression, diarrhea fistulas (especially biliary) and lack of intake extending over a period of several days. It is more apt to progress to a serious degree than sodium deficiency because potassium is excreted by the kidney in the presence of an existing deficiency, whereas sodium is conserved. Symptoms of hypopotassemia are inconsistent. The commonest one is weakness. Also encountered are anorexia, nausea, restlessness, diffuse pain, irrationality and stupor. It may be detected with a fair degree of accuracy by electrocardiographic examination. Alkalosis is a fairly constant accompaniment of hypopotassemia. Less commonly an increase of the nonprotein nitrogen is also present.

Levels of serum potassium below 3.5 milliequivalents are considered abnormal and constitute indications for potassium therapy. Potassium chloride is the drug best suited for therapy, but it must be given cautiously in the presence of renal insufficiency. In our experience a dose of 2 to 3 Gm. per day will do no more than replace daily loss. Dosage up to 6 Gm. per day usually will bring the potassium level to normal within a few days, except in patients who are losing large quantities of fluid by diarrhea, gastrointestinal decompression, urinary secretion or fistulas. In the presence of levels as low as 3.0 milliequivalents and good renal function, as much as 12 to 15 Gm. of potassium chloride may be given in as many hours. Thereafter the amount given must be reduced and be controlled by laboratory tests for potassium levels, aided perhaps by serial electrocardiographic tracings. As much as 6 Gm. of potassium chloride may be added to a liter of such fluids as 5 per cent glucose, 5 per cent amino acids and isotonic sodium chloride solution and given intravenously, but it should not be added to fluids already hypertonic.

With few exceptions, oral intake of food corrects hypopotassemia rapidly. If gastrointestinal decompression is to be carried out any longer than two days or if severe diarrhea or loss by other mechanism occurs, a prophylactic dose of 2 to 4 Gm. per day should be given to the patient.

EXPERIMENTAL BRONCHOTRACHEAL ANASTOMOSIS

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IN RECENT years there has been an increased interest in resection of segments of the bronchopulmonary tree. Frequently the proximity of lesions to the tracheal bifurcation makes resection impossible. Removal of the tracheal bifurcation and regional lymph nodes would necessitate the development of reconstructive procedures, in particular, anastomoses between the trachea and major bronchial divisions. If functioning anastomoses could be made without overwhelming risk, resections of this magnitude could be carried out. Such a surgical procedure might well extend the limits of resectability in dealing with lesions at or near the carina. The experiments herein reported were undertaken to determine the feasibility of performing a bronchotracheal anastomosis and the survival and function of transposed pulmonary tissue.

Taffel,[1] in 1940, published the results of his experimental work on the repair of tracheal defects in dogs. He created circular defects in the cervical trachea and covered these with fascial grafts. He observed that epithelial regeneration became apparent within two weeks. Daniel [2] found that when resected segments of cervical and thoracic trachea were bridged by metal or glass tubes there was a proliferative fibroblastic reaction about the tube, with a tendency toward stenosis at the anastomotic site. Epithelial regeneration took place over the scar tissue matrix in which were islands of imperfect cartilaginous rings. Grindlay, Clagett and Moersch [3] have reported on the use of polythene tubes in bridging tracheal defects in dogs. They found that although there was comparatively little reaction to the tubes they tended to become dislodged and lie free in the tracheal lumen. This same group

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1. Taffel, M.: The Repair of Tracheal and Bronchial Defects with Free Fascia Grafts, Surgery **8**:56, 1940.

2. Daniel, R. A.: Regeneration of Defects of the Trachea and Bronchi: An Experimental Study, J. Thoracic Surg. **17**:335, 1948.

3. Grindlay, J. H.; Clagett, O. T., and Moersch, H. J.: Experimental Surgery of the Thoracic Trachea and Its Bifurcation: Preliminary Report, Proc. Staff Meet., Mayo Clin. **24**:555, 1949.

has recently published a method for an experimental end to end bronchotracheal anastomosis, thus making resection of the carina, right main bronchus and right lung possible. Jackson and others [4] have performed several types of end to end bronchial anastomoses in dogs and have studied the regenerative and healing processes. They concluded that an everting anastomosis with approximation of mucosal surfaces was the most satisfactory method. Ferguson, Wild and Wangensteen [5] have resected segments of trachea 0.2 to 8.8 cm. in length and have anastomosed the proximal and distal divided tracheal segments under tension. These experiments, performed on dogs, were done both with and without preservation of a tracheal mucosal cuff. Tracheal homografts, tracheal autografts, costal cartilage, aortic homografts and tantalum gauze tubes were also used to reconstruct resected segments of cervical trachea. These same authors have performed end to end bronchotracheal anastomoses in eight dogs, six of which survive the procedure.

The experiments reported here were designed to demonstrate in dogs the feasibility of creating a bronchotracheal anastomosis at a point 3 to 5 cm. above the tracheal bifurcation without the use of tubes and to determine the functional capacity and fate of the transposed bronchopulmonary tissue.

METHODS

The animals used in the experiment were divided into two groups. In group I, a series of eight animals, an anastomosis was made between the distal end of the divided right upper lobe bronchus and the lateral wall of the trachea at a distance 3 to 5 cm. above the carina. Dogs weighing 10 to 25 Kg. were anesthetized with intravenous administration of pentobarbital sodium and atropine. A no. 9 endotracheal tube with an inflatable cuff was introduced into the trachea and attached to a M.S.A. Pneophore resuscitator.[6] A positive pressure of 10 to 15 cm. of water was maintained during the operative procedure. A posterolateral incision was made over the right third interspace and carried through the chest wall. The right lung was retracted ventrally, and the mediastinal pleura overlying the trachea was incised. The azygous vein was isolated, divided and ligated. The mediastinal pleura overlying the trachea and carina was dissected away, exposing the right upper lobe bronchus. The bronchus to the right upper lobe was isolated, and the bronchial artery to the lobe severed. This bronchus was clamped near the trachea and divided distal to the clamp. The proximal bronchial stump was closed with two layers of 000 silk suture. Further mobilization of the right upper lobe on its vascular pedicle was obtained by stripping away the pleura and fascia covering the vessels. This procedure allowed the divided distal end of the right upper lobe bronchus to be placed 3 to 5 cm. above the tracheal bifurcation without undue tension on the pulmonary vessels. A circular window 8 to 11 mm. in diameter was made in the right lateral wall of the trachea 3 to 5 cm. above the tracheal bifurcation. During the time that the trachea was open the stoma was occluded digitally for 60 seconds of each 90 second interval to allow adequate aeration of the lungs during this critical period. Six interrupted 000 silk mattress sutures were placed at positions of 2, 4, 6, 8, 10 and 12 o'clock on the tracheal wall 1 to 2 mm. from the edge of the stoma and were taken through the tracheal wall, then through the adventitia of the divided distal right upper lobe bronchus and back again through the tracheal wall. After placement of these six sutures, all were tied. This brought the divided distal end of the right upper lobe bronchus down to the newly created tracheal stoma and invaginated the end of the bronchus into the stoma. The anastomosis was made more secure by a few interrupted 000 silk sutures taken between the adventitia of the bronchus and the outer fibrocartilaginous part of the

4. Jackson, T. L.; Lefkin, P.; Tuttle, W., and Hampton, F.: An Experimental Study in Bronchial Anastomosis, J. Thoracic Surg. **18**:630, 1949.

5. Ferguson, D. J.; Wild, J. J., and Wangensteen, O. H.: Experimental Resection of the Trachea, Surgery **28**:597, 1950.

6. M.S.A. Pneophore, Mine Safety Applicances Co., Bradock, Thomas and Meade Sts., Pittsburgh 8, Pa.

Fig. 1.—The right hilar region after dissection of the mediastinal pleura and connective tissue. The right upper lobe has been retracted ventrally and can be seen in the upper left hand corner of the illustration. The right upper lobe bronchus lies immediately dorsal to the clamp. The right vagus nerve courses caudally from left to right over the right lateral aspect of the trachea to point *A*, where it gives off a branch to the right upper lobe. The pulmonary vascular pedicle has been mobilized by dissection and is shown at *B*.

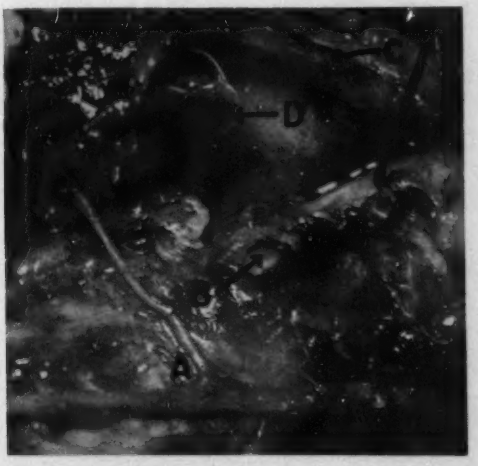

Fig. 2.—The right hilar region after division of the right upper lobe bronchus. The right vagus nerve can be seen coursing caudally from left to right. The vagal branch to the right upper lobe is shown at *A*. The proximal bronchial stump has been closed with two layers of 000 silk *B*. The pulmonary vascular pedicle has been further mobilized, as shown at *C*. The distal divided right upper lobe bronchus is pictured at *D*.

Fig. 3.—The right hilar region after creation of the tracheal stoma *B*. The vagus nerve *A* has been transposed to a position ventral to the closed bronchial stump. The pulmonary vascular pedicle *C* has been sufficiently mobilized so that the distal divided right upper lobe bronchus may be brought to the tracheal stoma without tension. One interrupted horizontal mattress suture has been placed on the ventral aspect of the tracheal stoma. This is to be an everting anastomosis.

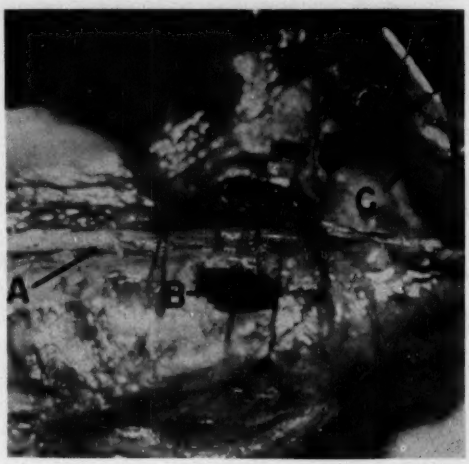

Fig. 4.—The right hilar region after placement of the four interrupted mattress sutures. The vagus nerve *A* lies in a position ventral to the tracheal stoma *B*. There is no tension on the pulmonary vascular pedicle *C*. The distal divided right upper lobe bronchus is being drawn up to the tracheal stoma.

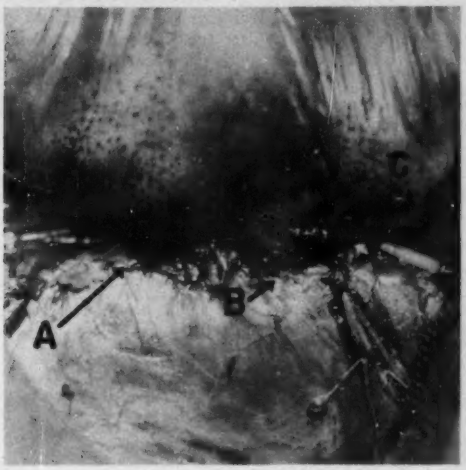

Fig. 5.—The right hilar region after completion of the bronchotracheal anastomosis and repleuralization of the operative site. The line of closure of the mediastinal pleura is shown at *A*. The anastomosis is covered by pleura *B*. The reexpanded upper lobe of the right lung *C* is shown in the upper half of the illustration.

Fig. 6.—The reexpanded right upper lobe. The appearance of the lobe is almost indistinguishable from its preoperative appearance.

trachea. The mediastinal pleura was closed over the operative site. The intrapulmonary pressure was then increased to 20 to 30 cm. of water and the transposed lobe reinflated. The postoperative appearance of the lobe was indistinguishable from its preoperative appearance. The chest wall was closed in layers. A catheter (no. 22 French) was left in the right pleural cavity and attached to a suction apparatus during the first postoperative hour and was then removed.

In group II, a series of nine animals, an anastomosis was made between the same structures and in the same anatomic location as in the previous group. In this group, however, the divided

Results of Preoperative and Postoperative Stud

Animal No.	Studies Following Right Upper Lobe Bronchotracheal Anastomosis		Left Pneumonectomy	Studies Following Left Pneumonectomy		Survival Following Bronchotracheal Anastomosis
	Roentgenologic	Bronchoscopic		Roentgenologic	Bronchoscopic	
9	Examination at 1, 2 and 4 mo., partial atelectasis of rt. upper lobe; no pleural effusion; no mediastinal shift	Examination at 1, 2 and 4 mo., progressive narrowing of the stoma	No	.....	.....	Killed, 6 mo.
10	No evidence of atelectasis	Examination at 6 and 12 wk. showed a patent stoma	6 mo.	No evidence of mediastinal shift; entire rt. lung well aerated	.....	Killed, 7½ mo.
11	.....	.....	No	.....	.....	Died 12th postoperative day
12	No evidence of atelectasis at 3 and 5½ mo.	Examination at 3 mo. showed a patent stoma	6 mo.	Right lung well aerated	Stoma appeared patent	Killed, 8 mo.
13	Partial atelectasis of rt. upper lobe	Examination at monthly intervals showed progressive narrowing but not occlusion	No	.....	.....	Killed, 5 mo.
14	.....	.....	No	.....	.....	Died 5th postoperative day
15	No evidence of atelectasis, pneumonia or pleural effusion	Examination at 1, 3 and 4 mo. showed a patent stoma with progressive healing and epithelization	4½ mo.	Examination at 5 mo. from original procedure showed no pneumonia or atelectasis	Stoma was patent	Killed, 5½ mo.
16	No evidence of pneumonia or atelectasis; lodized oil studies showed good filling of rt. upper lobe bronchus	Examination at ½, 3 and 7 mo. showed good healing of a patent stoma	No	.....	.....	Killed, 10 mo.
17	Atelectasis of rt. upper lobe which did not change with increased intrapulmonary pressure; lodized oil studies showed no filling of rt. upper lobe bronchus	Progressive narrowing to almost complete occlusion	No	.....	.....	Killed, 6 mo.

distal end of the right upper lobe bronchus was placed to form an everting cuff over the tracheal stoma. The surgical approach to the right upper lobe bronchus was the same as that described for the previous group. The bronchus to the right upper lobe was isolated, and the bronchial artery to the lobe was severed (fig. 1). The bronchus was clamped near the trachea and divided distal to the clamp. The proximal bronchial stump was closed with two layers of 000 silk (fig. 2). Mobilization of the hilar structures was carried out as previously described. A circular window 8 to 11 mm. in diameter was made 3 to 5 cm. above the carina on the right lateral wall of the trachea. Four interrupted 000 silk mattress sutures were placed at positions of 3, 6, 9 and 12 o'clock on the tracheal wall. Each stitch was taken through the edge of the divided distal right upper lobe bronchus, through the trachea: wall 2 to 3 mm. from the edge of the newly created stoma, and returned through these structures in the reverse order (fig. 3). After the placement of the four sutures all were tied, and the right upper lobe bronchus was

brought down to the tracheal wall over the new stoma (fig. 4). The end of the bronchus then formed an everting cuff on the tracheal wall. A running 000 chromic surgical gut suture was taken through the edge of the bronchus and the adventitia of the trachea about the entire circumference of the anastomosis. This served to seal the anastomosis and render it completely airtight. The mediastinal pleura was closed over the operative site (fig. 5) and the transposed lobe expanded under positive pressure (20 to 30 cm. of water). The postoperative appearance of the lobe was indistinguishable from its preoperative appearance (fig. 6). The chest wall was closed by layers.

ies of Dogs in Group II and Autopsy Findings

Percentage of Arterial Oxygen Saturation			Size of Stoma, Mm.							
Before Operation	After Bronchotracheal Anastomosis	After Left Pneumonectomy	Initial	Final	Decrease, %	Pleuritis	Atelectasis	Pneumonitis	Epithelization of Stoma	Other Developments	Result
....	....	....	8	3	63	Fibrous	Partial of rt. upper lobe	Mild interstitial	Yes	No evidence of bronchiectasis	Fair
98.4	97.1	92.7	10	8	20	Minimal fibrous	None	None	Yes	All lobes of rt. lung appeared normal	Good
....	....	....	8	..	..	Serous with effusion	Right upper lobe	Primarily rt. upper lobe	No	Lobar pneumonia involving primarily rt. upper lobe	Died
96.8	96.1	94.4	11	8	27	Minimal fibrous	None	None	Yes	.....	Good
....	....	....	11	5	56	Fibroserous with effusion	Partial of rt. upper lobe	Diffuse mild interstitial	Yes	No evidence of bronchiectasis	Fair
....	....	....	9	..	..	Fibrinous with serosanguineous effusion	None	None	No	Thrombosis of superior vena cava	Died
95	94.2	92.7	10	8	20	None	None	None	Yes	Gross and microscopic pictures, figs. 7 to 10	Good
96	93.5	....	11	8	27	None	None	None	Yes	All lobes appeared normal; no bronchiectasis present	Good
....	....	....	10	1.5	85	Fibroserous with effusion	Marked	Rather marked	Yes	No pathological changes in untransposed lobes	Poor

Preoperative and postoperative studies of the arterial oxygen saturation (method of Van Slyke and Neil [7]) of conscious animals breathing air were done on four dogs. Those animals that died during operation or during the postoperative period were studied grossly and microscopically to ascertain the cause of death. Animals that survived the procedure were studied bronchoscopically and fluoroscopically. Bronchospirometric studies were attempted but were unsatisfactory because of technical difficulties. An oximeter was used to measure relative changes in the arterial oxygen saturation during the surgical procedure, especially during construction of the anastomosis. The animals were killed 5 to 10 months after the bronchotracheal anastomosis, and gross and microscopic examinations were made of the lungs, bronchi,

7. Van Slyke, D. D., and Neil, J. M.: Determination of Gases in Blood and Other Solutions by Vacuum Extraction and Manometric Measurement, J. Biol. Chem. **61**:523, 1924.

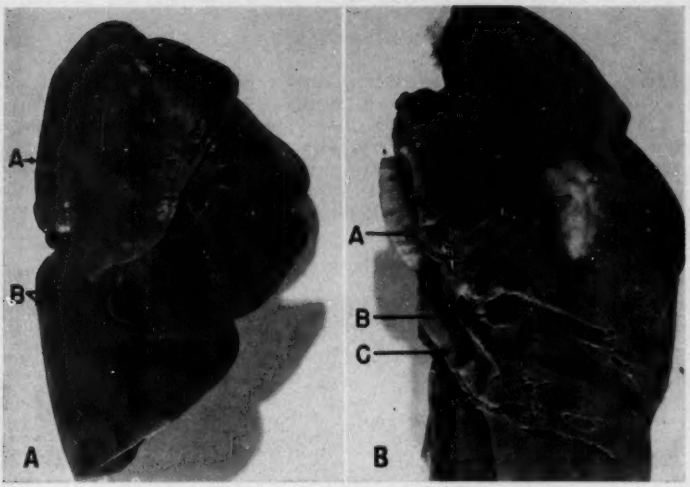

Fig. 7.—*A*, the right lung of dog 15. The bronchus to the right upper lobe was transposed to the lateral wall of the trachea five and one-half months before the dog was killed. The upper lobe *A* has the same external appearance as the untransposed middle and lower lobes *B*. *B*, coronal section through the right lung of dog 15. The anastomotic stoma *A* is 8 mm. in diameter; the original diameter was 10 mm. The untransposed bronchi to the middle lobe *B* and the lower lobe *C* are shown and have the same gross appearance as the transposed upper lobe bronchus. The pulmonary parenchyma has a normal appearance in all lobes.

Fig. 8.—The bronchotracheal anastomosis *A* in dog 15 viewed at its point of entrance into the lateral wall of the trachea. The trachea has been opened anteriorly and its left wall reflected laterally. The tracheal stoma has a smooth epithelized border. The closed bronchial stump *B* has healed and is covered by epithelium.

trachea and anastomotic site. The left lung was removed in three of the dogs four and a half to six months after the original operative procedure in an attempt to facilitate functional studies of the transposed bronchopulmonary tissue.

RESULTS

Group I (Inverting Anastomosis).—In this series of eight dogs the first three died of anoxia due to insufficient respiratory exchange during the time that the bronchotracheal anastomosis was being constructed. At this time, however, we were not using the M. S. A. Pneophore resuscitator. Of the remaining five animals, one died four hours postoperatively of tension pneumothorax caused by a small air leak through the bronchial stump; the other four dogs survived the operative and

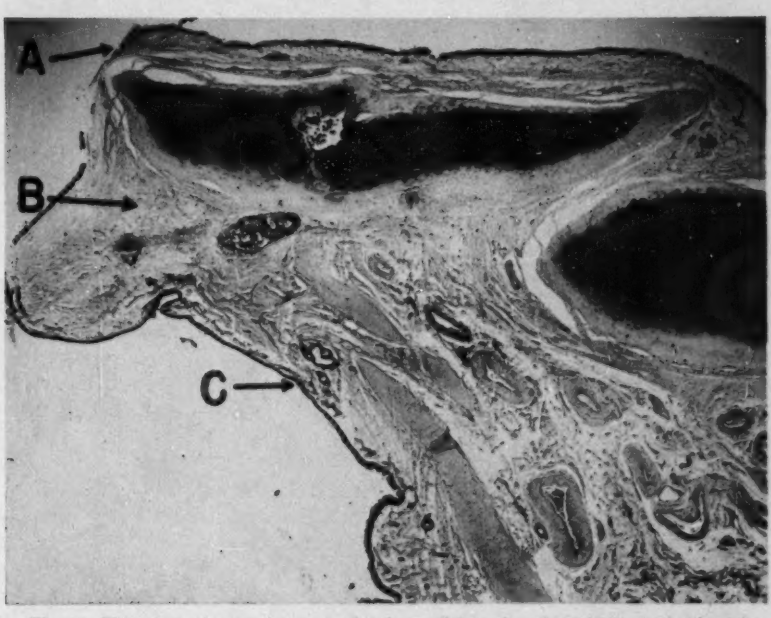

Fig. 9.—This photomicrograph was made of a radial section through the healed bronchotracheal anastomosis from dog 15. The tracheal mucosa *A* courses transversely along the upper border of the illustration. The dark masses lying beneath the tracheal mucosa are tracheal rings stained with hematoxylin. A silk suture lies in the center of a tracheal ring near *A*. At *B* a small amount of granulation and fibrous tissue has filled in the anatomic defect between the bronchus *C* and the wall of the trachea. Epithelium covers the granulation tissue at the bronchotracheal junction. This is an everting anastomosis.

postoperative periods and were killed four to seven months after operation. At autopsy three of these animals showed marked stenosis of the right upper lobe bronchus at the anastomotic site, with partial atelectasis and diffuse pneumonitis in the transposed lobe. The anastomosis was completely occluded in the remaining case, and the right upper lobe was completely atelectatic.

Histological examination of the anastomosis in the four surviving animals showed granulation and scar tissue about the edge of the inverted bronchial cuff. Epithelization had taken place over the site, but a considerable degree of stenosis was

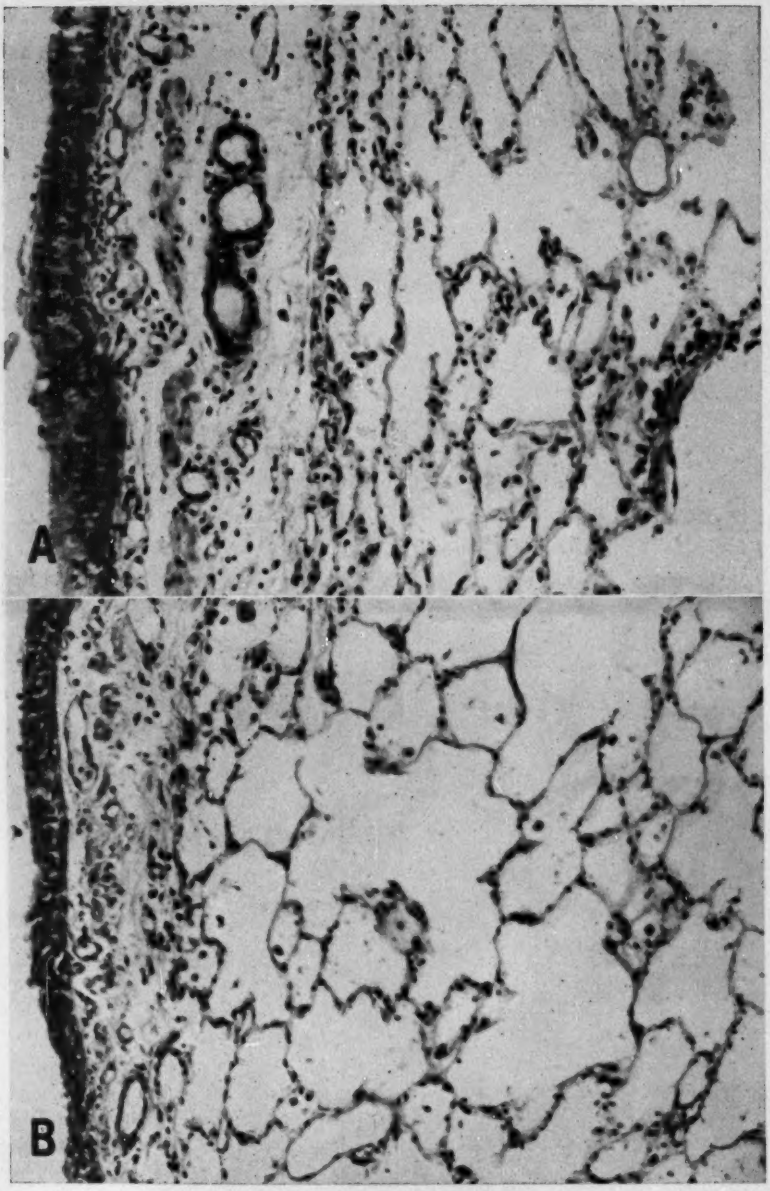

Fig. 10.—Photomicrographs of the bronchial wall and adjacent pulmonary parenchyma from the transposed right upper lobe *A* and from the untransposed right lower lobe *B* of dog 15 are shown. These sections are almost indistinguishable from each other histologically. There is no evidence of disease in bronchi or in pulmonary parenchyma in either section.

inevitably present. An inverting type of anastomosis did not afford close enough approximation of the mucosal surfaces to prevent scarring at the anastomotic site. In general this type of anastomosis was unsatisfactory.

Group II (Everting Anastomosis).—In this series of nine animals there were no operative fatalities. Two animals (nos. 11 and 14) died in the postoperative period, one on the twelfth postoperative day of pneumonia involving primarily the right upper lobe and the other on the fifth postoperative day of a thrombosis of the superior vena cava. Four of the dogs were considered as having a completely successful result (nos. 10, 12, 15 and 16), as judged by physiological studies during the postoperative period and by autopsy findings five to ten months after the original operative procedure. In three animals (nos. 9, 13 and 17) cicatricial narrowing of the tracheal stoma resulted in pathologic changes in the transposed bronchopulmonary tissue. The results in these three animals were classed as fair or poor. The results of preoperative and postoperative studies of the dogs in group II as well as the autopsy findings are summarized in the accompanying table.

Illustrations (figs. 7 to 10) of a successful transposition of the right upper lobe are given. In this animal (dog 15) a left pneumonectomy was done four and one-half months after transposition of the right upper lobe. The animal was killed one month after pneumonectomy. The external appearance of the lobes of the right lung is shown in figure 7 *A*. A coronal section (fig. 7 *B*) through the right lung shows no gross pathologic changes in the bronchi or the lung parenchyma. The anastomotic site is hemisected and is patent. The patent stoma (fig. 8) and the healed bronchial stump are shown. A section (fig. 9) taken through the anastomosis shows minimal granulation and scar tissue formation at the junction of bronchus and trachea. Eipthelization has occurred over the operative site. Sections taken from the transposed right upper lobe (fig. 10 *A*) and the nontransposed right lower lobe (fig. 10 *B*) show no pathologic changes.

COMMENT

Two major problems presented themselves in the development of the surgical technic: first, the maintenance of an adequate respiratory exchange during the period that the tracheal stoma was open and, second, cicatricial contraction of the anastomotic stoma. The use of the M. S. A. Pneophore is the most satisfactory method of oxygen administration in our experience. This machine maintains positive pressure through a controlled selected range during the operative procedure and allows reinflation of the transposed lung tissue after completion of the anastomosis. An endobronchial catheter is satisfactory but carries certain disadvantages with its use. The placement of an endobronchial catheter is rather difficult because the left main bronchus of a dog is short, usually about 1 cm. in length. If the cuff is near the carina, it is easily dislodged or obstructs the operative site. If placed too far down the left main bronchus, it will not adequately aerate both upper and lower lobes on the left side. In our experience an endotracheal tube, used in conjunction with an M. S. A. Pneophore resuscitator, is satisfactory provided the tracheal stoma is occluded digitally for 60 seconds of each 90 second interval. This allows careful placement of sutures and yet maintains adequate oxygen exchange.

Cicatricial contraction of the anastomotic stoma was minimized by the use of an everting type of bronchotracheal anastomosis. In anticipation of some narrowing in all cases, the bronchus to be transposed should be severed in such a manner as to

preserve the greatest cross sectional diameter, using an oblique cut on the bronchus if possible, and the tracheal window should be made as large as feasible. With eversion of the divided distal end of the bronchus at the site of the anastomosis, the cross sectional area is not reduced as it is when an inverted type of anastomosis is made. Furthermore, in the everted type of anastomosis the mucosal surfaces are more nearly approximated and narrowing of the stoma by granulation tissue is minimized. The everted type of anastomosis was technically less difficult and could be sealed more securely with a layer of running surgical gut along the everted edge of the bronchus. As shown above, our results with the everting type of anastomosis have been better than those with an inverting anastomosis.

An essential step in the procedure is adequate mobilization of the lobe on its vascular pedicle. After division of the bronchus, care must be taken to free the pulmonary vessels of their pleural and fascial coverings. When this is done, it is possible to perform the anastomosis without undue tension at the suture line.

After completion of the previously described experiment, namely transposition of the right upper lobe to the trachea, we felt convinced that it would be feasible to extend the procedure to transposition of the right main bronchus to a higher level on the trachea. Such a transposition of the main bronchus would allow subsequent resection of the entire left lung, carina and regional lymphatic vessels in an en bloc dissection. The development of such a reconstructive procedure would allow a more adequate approach to tumors in this region.

It has been well established that the pulmonary artery to either lung may be ligated provided the bronchial artery supply remains intact.[8] It has been stated that while a bronchial artery to one lobe may be ligated the entire bronchial arterial supply to a lung cannot be sacrificed without death of the pulmonary tissue.[9] Otherwise stated, it would mean that the pulmonary arterial supply alone will not sustain the viability of the lung. We cannot agree with this statement. Though this portion of our study is in a preliminary stage, it is felt that the results obtained to date are of significance and should be reported.

At the present time we are conducting a series of experiments in which the right main bronchus is being transposed to the lateral wall of the trachea 3 to 5 cm. above the carina. To date this procedure has been performed on six animals. Two of the six animals died in the immediate postoperative period of tension pneumothorax. In the four surviving animals the left lung was removed within two to four months after the right bronchotracheal anastomoses were performed. One animal died shortly after removal of the contralateral lung. Postmortem examination in this animal showed marked stenosis of the anastomotic stoma, with secondary atelectasis and pneumonitis in the transposed lung. The three remaining animals survive from 12 to 30 hours after removal of the left lung. During the immediate postoperative period it appeared that adequate pulmonary function was maintained by the transposed right lung. Postmortem examinations of these three dogs showed a persistence of the large stoma and anatomically normal bronchopulmonary tissue

8. Bloomer, W. E.; Harrison, W.; Lindskog, G. E., and Liebow, A. A.: Respiratory Function and Blood Flow in the Bronchial Artery After Ligation of the Pulmonary Artery, Am. J. Physiol. **157**:317, 1949.

9. Ellis, F. H.; Grindlay, J. H., and Edwards, J. E.: Experimental Study of the Effect of Occlusion of the Bronchial Arteries: Clinical Congress of American College of Surgeons, October 1949, p. 78.

in the transposed right lung. The unexplained death of these three animals was thought possibly to be due to a complete severance of the nerve supply to all of the remaining pulmonary tissue.

SUMMARY

The bronchus of the upper lobe or the main bronchus of the right lung was transposed to the lateral wall of the trachea at a level 3 to 5 cm. above the tracheal bifurcation in 23 dogs. In 17 animals the bronchus of the upper lobe of the right lung was transposed. In eight dogs the divided end of the bronchus was sutured inside the artificial tracheal stoma. Four of these animals died during the surgical procedure or in the immediate postoperative period. Pronounced stenosis developed at the anastomotic site in the four remaining animals. In nine dogs the divided end of the bronchus was anastomosed so that it formed an everting cuff on the outer wall of the trachea. Two in this group died within 12 days, one of pneumonia and the other of thrombosis of the superior vena cava. The seven remaining animals survived and were killed within five to 10 months after the bronchotracheal anastomosis. Three of the animals showed moderate to severe stenosis of the anastomotic stoma, with secondary pneumonitis and atelectasis in the transposed lobe. In four animals the transposed bronchopulmonary tissue showed microscopic, physiologic and clinical evidence of normal structure and function.

In six animals the divided end of the right main bronchus was everted and transposed to the lateral wall of the trachea. Two animals died in the immediate postoperative period of tension pneumothorax caused by leaks from their bronchial stumps. The normal left lung was removed from the remaining four animals within two to four months after the bronchus of the right lung had been transposed. One animal died shortly after removal of the contralateral lung. His anastomotic stoma had undergone severe stenosis. Three animals survived from 12 to 30 hours after removal of the untransposed left lung. It appeared that during the immediate postoperative period adequate pulmonary function was maintained by the right transposed lung and main bronchus.

DISCUSSION

DR. EDWIN M. MILLER, Chicago: No one from our laboratories is making any extravagant claims for this work, since it is purely in the experimental stage, as you can readily see. It is valuable, however, in that it is one of several serious attempts to extend the limits of resection to include carcinomas and other lesions of the tracheobroncheal tree which involve the carina.

This work differs from that of Wangensteen and his group in that the anastomoses have been made end to side in contradistinction to theirs, which have been end to end, and I believe that is also true, Dr. Grindlay, of the technic employed by your men in the laboratory at the Mayo Clinic. It may have an advantage over the end to end anastomoses because discrepancies in diameter may be more easily handled than when the end to end method is employed. Also, the transposed bronchus, when joined to the trachea end to side, will come off at a more normal angle and will require less extensive mobilization at the root of the lung and therefore less interference with the blood supply through the bronchial artery.

It is thought that if this experimental work proves to be consistently successful in dogs and the opposite lung can be removed at the same time, there will be a reasonable hope that the technic employed may be applicable to human beings.

DR. JOHN DORSEY, Chicago: Other men, several of them members of this Association, who, during the period that this work was in progress, have presented excellent work along the same lines are Dr. Tuttle, Dr. Grindlay, Dr. Clagett and Dr. Wangensteen. I hope they will continue this discussion.

The significance of the work perhaps points in two directions, one of which has been alluded to in Dr. Tuttle's publications, namely, the preservation of lung tissue. By the application of these methods of anastomosis in the removal of benign tumors and strictures, pulmonary tissue can be preserved. The other direction, to which Dr. Ehrlich referred and of which Dr. Miller spoke, is in the resection of malignant lesions about the hilus. The fact that during this period it has been possible to show that this type of anastomosis can be made is encouraging. We hope that as experimental work is continued, such as that reported by Dr. Jouvenelle at the 1950 meeting of the American Thoracic Society, in which not only an end to end anastomosis was made but also an end to side anastomosis of the opposite side on the trachea above, new methods will be added to the armamentarium of the surgeon, so that the resectability and curability of bronchogenic cancer involving these hitherto unresectable portions of the bronchogenic tree will be increased.

DR. WILLIAM TUTTLE, Detroit: I want to congratulate the authors on their presentation. We have been interested in this work for a considerable period of time. I believe that the procedure is also applicable and feasible in human beings, from an experience of my own which occurred three and a half years ago.

The patient had previously undergone an old snare type of lobectomy, and in the process the superior division of the lower lobe apparently had been left in. He came back bleeding, and it was evident at that time that he had a considerable amount of bronchiectasis in what we thought was only the lingula. We found that he had a considerable amount of bronchiectasis in the remaining superior division which we did not recognize had been left in.

In the process of getting off the superior division and the lingula, I got a little mixed up when I made the incision across the bronchus and I cut off the upper lobe bronchus. It was then a case of either sacrificing the upper lobe remaining above the lingula or trying to anastomose the upper lobe bronchus end to end to the left main bronchus. This I did, with straight interrupted silk sutures. The following day the patient had good breath sounds over the area, but three days later he became completely blanked out. Bronchoscopy was performed, and the lumen was wide open, the plug apparently having been coughed out during the process of preparing the patient. It looked much like a lower lobe at this time because the lobe had been swung around, and the upper lobe bronchus then became a continuous passage with the left main bronchus.

He made an uneventful recovery and went back to work. About a year and half later he returned again, bleeding. At that time he was bleeding from a small area of bronchiectasis which we knew he had in his right pectoral division. Bronchoscopy was performed at that time, and the opening from the left main bronchus into the upper lobe bronchus was perfectly normal in appearance. There was no stenosis. We then did a segmental resection on the pectoral division on the right side. That has been about two years ago, and he is still perfectly well. The upper lobe, which is now in direct continuity with the left main bronchus, is still well aerated.

ARTERIAL HOMOGRAFTS

III. Use of Preserved Grafts in the Treatment of Neoplastic Disease Involving Peripheral Arteries

HENRY SWAN, M.D.
AND
H. MASON MORFIT, M.D.
DENVER

THE USE of homogenous arterial grafts in the aorta has been demonstrated to be practical both experimentally and clinically for periods up to at least two years.[1] Previous communications from our laboratory have described the fate of experimental preserved aortic grafts and the clinical use of this technique in the resection of a thoracic aortic aneurysm.[2] Experimentally, smaller arterial transplants were recently investigated and found to function effectively as conduits for blood.[3] The method, therefore, appears to offer the possibility of enlarging the scope of operative procedures for lesions involving peripheral arteries.

Several such possibilities come at once to mind. In localized inflammatory, degenerative or traumatic conditions of important peripheral arteries, the ability to perform resection followed by insertion of a replacement for the diseased segment should solve many of the current difficulties in the treatment of arterial aneurysm, arteriovenous fistula and acute traumatic injury of crucial arteries. The potentiality of this technique in military medicine might thus prove to be extensive.

In addition, arteries may become involved by neoplastic disease. In certain circumstances the limiting factor precluding adequate resection of a malignant growth is the discovery that it surrounds or invades an artery which cannot be sacrificed without extreme risk to the organ which it nourishes or even to the life

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Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

From the Bonfils Tumor Clinic and the Department of Surgery, University of Colorado School of Medicine.

1. Peirce, E. C., II; Rheinlander, H. F.; Moritz, A. R.; Gross, R. E., and Merrill, K., Jr.: Transplantation of Aortic Segments Fixed in 4 Per Cent Neutral Formalin: Report of Experiments in Dogs, Am. J. Surg. **78**:314-323 (Sept.) 1949. Gross, R. E.; Bill, A. H., Jr., and Peirce, E. C., II: Methods for Preservation and Transplantation of Arterial Grafts: Observations on Arterial Grafts in Dogs; Report of Transplantation of Preserved Arterial Grafts in 9 Human Cases, Surg., Gynec. & Obst. **88**:689-701 (June) 1949.

2. (*a*) Swan, H.; Robertson, H. T., and Johnson, M. E.: Arterial Homografts: I. The Fate of Preserved Aortic Grafts in the Dog, Surg., Gynec. & Obst. **90**:568-579 (May) 1950. (*b*) Swan, H.; Maaske, C.; Johnson, M., and Grover, R.: Arterial Homografts: II. Resection of Thoracic Aortic Aneurysm Using a Stored Human Arterial Transplant, Arch. Surg. **61**:732-737 (Oct.) 1950.

3. Miller, H. H.; Callow, A. D., and Welch, C. S.: The Fate of the Arterial Graft in Small Arteries; abstracted, Bull. Am. Coll. Surgeons **35**:55-56 (Jan.) 1950.

of the patient. The ability to extend the radical attack on the neoplasm by including resection of the involved arterial segment, followed by a suitable replacement to restore the vital blood flow, should enable the surgeon in selected circumstances to execute wide removal of the tumor and to diminish significantly the mutilating aftermath of such resection. The present paper reports on three patients in whom this concept was given clinical trial.

The use of this technique presupposes the availability of arterial grafts, and thus a stored supply or "artery bank" becomes essential. The problems involving such a bank have not yet been entirely solved. These problems are under current investigation in several laboratories. The grafts used in two of our patients were arterial segments stored in the blood bank refrigerator at 4 C. in a Mason jar containing Ringer's solution to which had been added 10 per cent by volume of human plasma together with small amounts of penicillin and streptomycin. However, arteries are not always easy to obtain. At the present time, we feel that the following criteria should be observed in selecting a homogenous artery as a graft: 1. The artery should be removed from a person between 10 and 35 years of age. 2. The donor must not have died from any disease whose transmission to the recipient is a possibility.[4] 3. The artery should be removed within four hours of death. 4. Use of a graft stored in excess of a three month period is not recommended.

At the time of admission of our first patient, no suitable vessel was on hand. Operation was delayed for five weeks in an attempt to secure one, but a suitable opportunity did not occur within that time despite a search made in the clinical material from four large hospitals in a community of 500,000 persons. Since further delay seemed unwise, an alternate method for bridging the arterial gap, an autogenous vein graft, was necessarily employed. In the second case, a delay of four weeks was likewise encountered.

REPORT OF CASES

CASE 1.—Mr. M., a 75 year old white retired truck driver, entered the surgical service at Colorado General Hospital on March 7, 1949, complaining of a firm tender lump in his right upper thigh. When first noticed 18 months previously, the mass was about the size of a marble. It had been steadily growing and during the two months prior to the patient's admission had occasioned him considerable pain and discomfort. For the past seven years, the patient had been under treatment in the medical outpatient department for hypertensive arteriosclerotic heart disease with auricular fibrillation and had remained fairly well with administration of digitalis. In addition, two years previously dietary management of mild diabetes had been instituted. When he was first seen in the surgical tumor clinic four days before his admission, the mass in the upper anterior aspect of the right thigh was noted to be approximately 7 cm. in diameter and apparently arose from the soft tissues. It was fixed to the underlying fascia but not to bone. An aspiration biopsy was performed and admission to the hospital arranged. The biopsy diagnosis was "soft part sarcoma, type undetermined." Study in the hospital revealed the blood pressure to be 160/100, the heart to be enlarged and fibrillating and the urine to contain sugar occasionally. The pulses in the right lower extremity distal to the tumor were weaker than those in the left. No evidence of tumor metastasis could be found.

It seemed clear, because of the location of the tumor and the diminished pulses distally, that excision of this tumor would surely require resection of the femoral artery. The possibility of the extremity surviving femoral artery ligation in an arteriosclerotic 75 year old man with auricular fibrillation seemed remote. Accordingly, the decision was made to attempt an arterial transplant. Since no suitable vessel was then available in our "artery bank," the patient was discharged, to be called in when a vessel was obtained. In spite of the alert cooperation of four

4. For example, overwhelming septic disease, virus disease or leukemia.

large general hospitals in the area, no suitable opportunity for obtaining a vessel occurred during the next four weeks. Since further delay seemed unwarranted, the patient was readmitted for operation, and it was planned to use a vein graft if arterial resection proved necessary (fig. 1).

On April 18, 1949, a block dissection with wide skin excision was performed, including all muscular and fascial structures surrounding the firm tumor. The superficial femoral artery was found to enter the tumor above and to emerge with its lumen considerably narrowed below. The deep femoral vessels were not involved in the tumor. Resection, therefore, included a segment of superficial femoral artery about 2 inches (5 cm.) in length together with the accompanying vein. With the use of a segment of the deep femoral vein which had thickened walls containing sclerotic plaques, the gap in the artery was bridged with suture technique.[5] On release of the temporary arterial clamps, the graft was seen to bulge somewhat, but there was

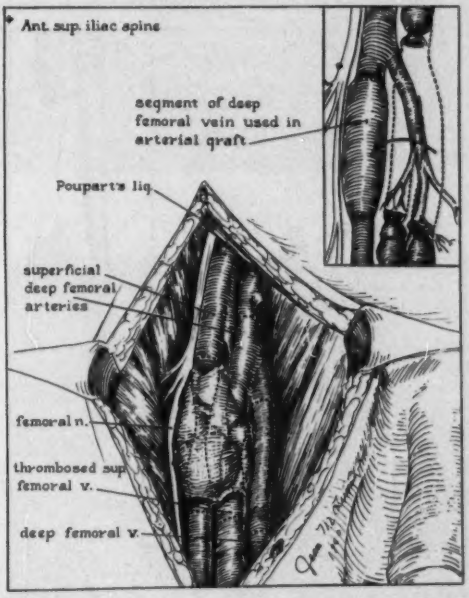
Ant. sup. iliac spine
segment of deep femoral vein used in arterial graft
Poupart's lig.
superficial & deep femoral arteries
femoral n.
thrombosed sup. femoral v.
deep femoral v.

Fig. 1.—Semidiagrammatic sketch of the operative findings and vascular reconstruction in case 1.

no palpable thrill and blood flow appeared excellent. When the wound was closed, there appeared to be some tension on the suture line because of the wide skin excision.

Postoperatively, the patient did well; the foot remained warm although arterial pulsations were barely palpable and were definitely less on the involved side than on the opposite side. The patient's diabetes remained under control. Moderate separation of the wound occurred which prolonged hospitalization during secondary skin grafting to obtain closure. In retrospect, the patient should have been placed in a hip spica postoperatively to assist wound healing, as is our custom with all patients in whom radical dissection of the groin has been carried out.

Since the procedure involved the resection of both the superficial and the deep femoral veins together with the greater saphenous vein, it is not surprising that there was considerable edema of the extremity postoperatively. However, with the aid of an elastic bandage this swelling

5. Ordinarily we would prefer to avoid the use of any graft in which atheromatous disease is present. The absence of any such disease is one advantage of the homogenous arterial transplant.

was kept from being excessive, and the leg remained comfortable and functional. The patient was discharged from the hospital in good condition, and when he was seen in October 1950, one and one-half years after operation, the right femoral pulse and the right anterior tibial pulse were palpable. The patient is leading an active life and having minimal edema with the use of the elastic bandage. There has been no evidence of local recurrence of the tumor or of distant metastases. The pathologic diagnosis was neurogenic sarcoma.

Case 2.—Mrs. M. H., a 33 year old housewife, was seen in consultation on Sept. 25, 1949, at the Fitzsimons General Hospital. Seven years previously a small tumor was noted in the region of the right femoral triangle. During the intervening years, three operative attempts at removal of the tumor had been made, the last one about two years previously. The pathologic diagnosis had been established as neurosarcoma. At the time of this admission, the tumor had recurred under the upper end of the incisional scar about 2 inches (5 cm.) below Poupart's

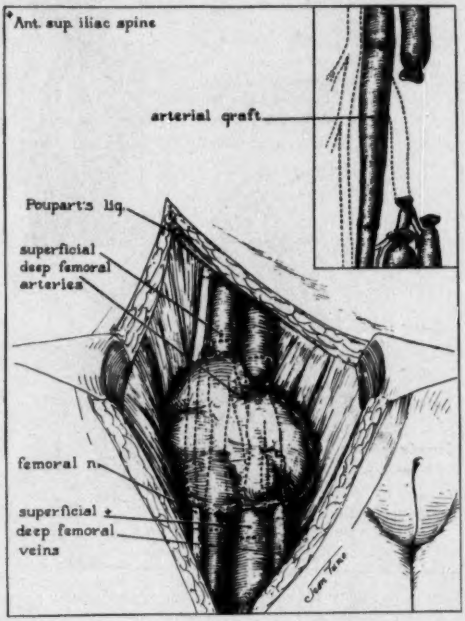

Fig. 2.—Semidiagrammatic sketch of the operative findings and vascular reconstruction in case 2.

ligament and measured approximately 3 by 4 cm. in size. It was not attached to bone and was movable beneath the skin, and it appeared to lie directly over the course of the femoral vessels. Once again at this time we had no vessel in our "artery bank" which was not outdated, and a period of four weeks elapsed before a suitable vessel was obtained for transplantation, in spite of the fact that the aid of four large army general hospitals as well as our own local hospitals was enlisted. Three such vessels were then obtained almost simultaneously, and accordingly operation was undertaken on Oct. 26, 1949 (fig. 2).

The tumor was excised en bloc with a liberal margin of tissue on all sides. It was found that the tumor enclosed the common femoral artery and vein at a point just above the bifurcation. Its origin appeared to be from the femoral nerve. Accordingly, a long segment of femoral nerve together with sections of femoral artery and vein including the bifurcation were removed with the tumor. The deep femoral vessels were ligated. To bridge the arterial defect a segment of brachial artery obtained at operation from a young man having a disarticulation of the shoulder

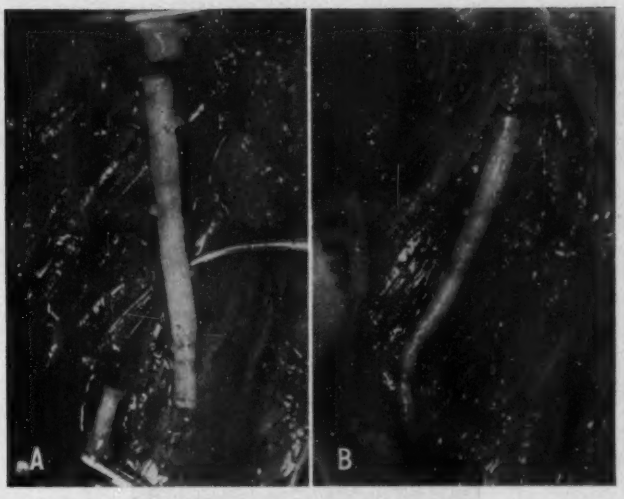

Fig. 3.—*A*, the arterial graft before insertion in case 2. *B*, after insertion of the graft, blood flow is resumed. Note the even contour of the reconstructed vessel.

Fig. 4.—An arteriogram made one year after operation outlines the apparently normal lumen of the reconstructed femoral artery in case 2.

seven days before was utilized. The graft was 8 cm. in length and matched rather well in size the patient's common femoral artery at the upper end and superficial femoral artery at the lower end. After removal of the temporary clamps, the blood flow seemed satisfactory (fig. 3). Muscles were approximated over the vessels, and the skin was closed primarily. On the venous side, of course, the operation included ligation of the superficial and deep femoral and the saphenous veins. The patient was placed in a hip spica to facilitate primary healing.

Postoperatively, her course was uneventful. There was moderate swelling of the extremity, which remained warm with palpable pulsations distally. The edema has been reasonably controlled with the use of an elastic bandage. The muscular disability caused by resection of the femoral nerve has been largely overcome by the strong will of the patient to reeducate herself in the use of her leg. At the present time, one year after operation, she leads a normal life which

Fig. 5.—A photograph of the lower extremities shows the moderate swelling but good function of the right leg six months after operation in case 2.

includes going to dances with her husband. The artery appears normal on arteriography. There is no evidence of recurrence of the tumor, which proved to be neurogenic sarcoma (fig. 5).

Case 3.—W. K., a 79 year old man, was admitted to the Colorado General Hospital on Jan. 20, 1950, with a tumor in the right femoral region which had been growing rapidly in the past year and a half. About ten years before his admission, he noticed a small nodule in this area about the size of a marble. The mass remained relatively unchanged in size until about one and one-half years previously, when it began to enlarge slowly until it approximated the size of a hen's egg. Three months before his admission, partial excision was carried out in another hospital. The pathologic report was "anaplastic sarcoma." After the partial excision the tumor began to grow rapidly, and at the time of the patient's admission it was a somewhat lobulated, purplish red, highly vascular mass over the femoral triangle on the right side. The leg was edematous, and there were diminished pulsations in the right peripheral arteries as compared with those in the opposite leg. The tumor invaded the overlying skin and was adherent

to underlying fascial tissues but was not fixed to bone. On the day of admission a needle biopsy was performed, which confirmed the diagnosis of sarcoma. The chest roentgenogram was normal, and no other evidence of metastasis was present. The patient had advanced arteriosclerotic heart disease with compensated heart failure when given digitalis therapy.

On Jan. 30, 1950, resection was undertaken (fig. 6). The tumor appeared to arise just beneath and lateral to the femoral vessels but did not involve the femoral nerve. The common femoral vein traversed the tumor and was thrombosed; the lateral wall of the femoral artery at the bifurcation was firmly attached to the tumor. The block resection included parts of all structures adjacent to the tumor, the external oblique fascia, Poupart's ligament and ileopsoas and pectineus fascia, as well as the right testicle and the spermatic cord. The portion of artery resected was about 2 inches (5 cm.) in length and included the bifurcation. An arterial homograft 5 cm. in length obtained from a 30 year old man killed in a cave-in 44 days previously was used to bridge

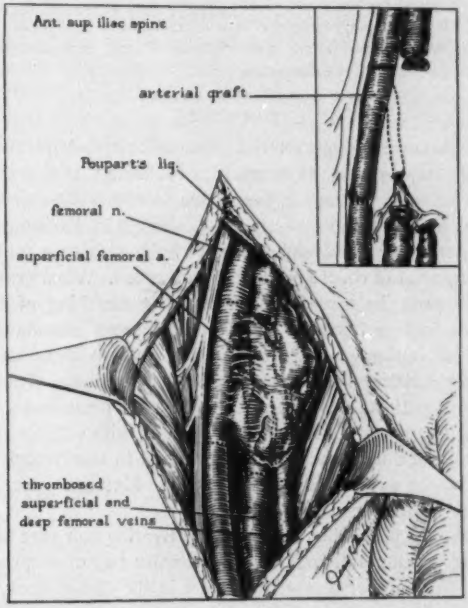

Fig. 6.—Semidiagrammatic sketch of the operative findings and vascular reconstruction in case 3.

the gap. After the suture anastomosis, the blood flow appeared adequate and palpation of the dorsalis pedis revealed a strong pulsation. Fifty milligrams of heparin was injected into the artery above the graft. Closure was extremely difficult because of the wide resection. An attempt was made to cover the graft by pulling muscle flaps over the top, and this appeared to have succeeded. The skin defect was so extensive that split-thickness grafts were used to cover the wound. A hip spica was applied, and the patient returned to the ward, having tolerated the procedure well.

During the next week his course was uneventful, and the extremity was warm with good arterial pulsations and minimal swelling. However, six days after operation, at the time of the first change of dressing, a most alarming situation was found. The muscle bellies which had been pulled across to bury the graft had separated, and in the center of the wound a small area of skin graft had melted away, exposing about 1 cm. of the upper segment of the arterial graft which could be seen pulsating well but which was completely uncovered. The following morning, therefore, a sliding flap from the scrotum was pulled across the wound in order to cover this

defect. That evening the graft ruptured at the site where it had been exposed, and severe exsanguinating arterial hemorrhage took place. With multiple transfusions the circulating blood volume was restored while temporary clamps were applied to the femoral artery to control hemorrhage. The patient was rushed to the operating room, where an attempt was made to repair the graft by suture reenforced with gelfoam® (absorbable gelatin sponge). Hemorrhage was controlled, and the wound was again closed, with the use of a pedicle skin flap together with muscle flaps swung from the lateral portion of the leg. However, 12 hours later he suffered from another acute exsanguinating arterial hemorrhage, which was again controlled by temporary compression of the vessels. His general condition was restored by vigorous transfusions. At this point, it became evident that we were jeopardizing the patient's life by further attempts to save his leg. Accordingly, defeat was admitted, the patient was taken to the operating room, and the common femoral artery was ligated. Since the gangrene which developed ended just below the knee, a supracondylar amputation was performed three days later. After this, the patient made an uneventful recovery and at the present time is leading an active life with the aid of crutches, which he has learned to use with extraordinary facility for a man of 80 years with arteriosclerotic heart disease. There is no evidence of local or metastatic recurrence of the tumor, which was found to be a rhabdomyosarcoma.

COMMENT

We feel that the success of an arterial homograft depends primarily on technical factors relating to its insertion, although it is probable that a graft which has not been stored in excess of 90 days is preferable to one with a greater duration of storage.[2a] Meticulous attention to asepsis, delicacy in handling of the tissues, avoidance of desiccation and careful suture technique, factors common to all vascular anastomoses, must of course be carefully observed. When grafting is involved, additional factors must be considered. The exact matching of the graft to the recipient vessel at both ends of the defect is of primary importance. Any sudden change in the caliber of the vessel at a suture line has been demonstrated experimentally to be a strong initiating factor for thrombosis and failure. Moreover, as demonstrated in the third patient, the closure of the wound must be so devised that the grafted artery shall be totally and completely covered with viable soft tissue. We feel sure that this is the technical factor which resulted in the breakdown of the graft and the failure of the procedure in this patient. Extreme care, therefore, must always be taken to insure adequate closure.

We believe that the possibility of adequately treating soft part sarcomas without routinely resorting to amputations, hemipelvectomies and other procedures productive of lasting deformity deserves a greater place in the plan of treatment. For many years it was passed down as an axiom to younger surgeons that when it was found necessary to perform an amputation for malignant bone tumor the amputation must be performed at a level at least as far proximal as the next major joint, for example, amputation for an osteogenic sarcoma located in the tibia should be done at or above the knee joint and amputation for osteogenic sarcoma at the lower end of the femur should involve hip joint disarticulation. Over the ensuing years there have been enough cases in which this axiom has been ignored to enable us to state with some surety that the value of this original concept has been largely disproved. It has now become the practice to carry out high thigh amputations for osteogenic sarcoma located at the lower end of the femur. If this departure from the old axiom of proximal joint amputation had proved wrong, clinical evidence would consist of recurrences in the soft tissues or the bone of the stump. Coley [6] has shown that

6. Coley, B.: Neoplasm of Bone, New York, Paul B. Hoeber, Inc., 1949.

such stump recurrences do not result after high thigh amputations except in the rarest of instances. Most deaths from osteogenic sarcoma result from distant metastases, and local recurrences in the stump are not a problem.

It is our belief that in selected cases, soft part sarcomas likewise can be adequately resected without necessarily resorting to amputations. It is certainly true that a review of the histories of patients with neurogenic sarcoma, fibrosarcoma, synovioma, and similar tumors will show that local recurrences following limited surgical removal have been frequent. In one case presented here today, the patient had been previously operated on three separate times. We have a feeling that it is the fear of damaging or sacrificing vital nerves or vascular structures which has prevented adequate removal in the initial operative attack in many such cases.

On previous occasions we have noted the practicality of sacrificing such structures as the main veins in an extremity and, on some occasions, a major nerve trunk and still leaving the patient with the functional result that far supersedes that which can be obtained through the use of prostheses following amputation. Specifically, we have found that when the femoral nerve is totally sacrificed a useful limb is still possible through the innervation of remaining muscle groups carried by the obturator and sciatic nerves. Similarly, we have sacrificed the sciatic nerve and found the patient able to carry on provided the femoral nerve is preserved.

Up to the present time, despite recognition of the above facts, our ability to circumvent the tumor in some cases has been blocked by the ill effects resulting from interruption of a main arterial vessel. That is, although it may have been possible to circumvent the tumor adequately by sacrificing major muscle groups, nerves and veins, nevertheless, if the main artery was sacrificed, gangrene was such a routine complication that amputation was usually resorted to as the initial procedure, despite the fact that adequate removal of the tumor could be accomplished without sacrificing remaining major neuromuscular groups which would leave the patient with a functional result better than any that could be obtained by the usual prosthetic restoration.

We should not like our remarks construed as a plea for limited surgical attack on malignant soft part tumors. Nevertheless, we feel that in selected cases it is possible to carry out radical excision of these growths and leave behind weight-bearing and neuromuscular components whose additive value supersedes that of ordinary prosthetic restoration. These cases demonstrate that the barrier to removing such sarcomas, even though they may be invading a major arterial vessel, can be eliminated.

SUMMARY

Three patients have been presented in whom radical local excision of sarcoma in the right femoral area of necessity included significant portions of the femoral artery. The gap in the arteries thus created was repaired by the insertion of arterial homografts in two patients and of a free autogenous venous graft in the third. Good functional survival of the limb was obtained in two patients, but failure was experienced in the third because of inadequate wound closure.

The use of a preserved arterial homograft for bridging large defects in main peripheral arteries seems to offer considerable promise as an adjunctive technique in the adequate resection of certain peripheral malignant neoplasms.

SURGICAL TREATMENT OF PULMONARY STENOSIS WITH INTACT INTERVENTRICULAR SEPTUM

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AND
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STENOSIS of the pulmonary valve is the only abnormality of note in a small but significant number of patients with cyanosis due to congenital heart disease. The pathologic process in such patients differs from that seen in typical tetralogy of Fallot in that the interventricular septum is intact and consequently there can be no overriding of the aorta. Instead of stenosis in the infundibular region as usually seen in the tetralogy of Fallot, stenosis in these cases is caused by fusion of the cusps of the pulmonary valve (fig. 2 *D*). The degree of this fusion, varying from negligible to complete, determines the severity of the symptoms.

Immediately distal to the stenosis marked dilatation of the pulmonary artery is usually seen. It is mysterious that poststenotic dilatation of the pulmonary artery is practically always present although pressure in the pulmonary artery is low. In fact, patients with the severest pulmonary stenosis, and consequently the lowest intrapulmonary pressure, are apt to have the most pronounced dilatation of the pulmonary artery.

The only other commonly associated lesion often seen in these hearts is a patent foramen ovale which serves as an escape valve into the left auricle for blood dammed back in the right auricle. The size of this shunt from right to left determines the degree of cyanosis.

Because the only significant lesion is in the pulmonary valve, this type of congenital heart disease is conveniently referred to for the sake of brevity as "pure pulmonary stenosis" and will be so designated in this paper.

Clinical differentiation of patients with pulmonary stenosis and an intact interventricular septum from those with an interventricular defect requires the utmost in diagnostic acumen and frequently necessitates the use of angiocardiograms and cardiac catheterization. The diagnosis in all patients forming the basis of this report was made by Dr. Stanley Gibson. Catheterizations when required were performed by Dr. James Campbell, and angiocardiographic studies were made by Dr. Harvey White. In a previous communication Gibson and others,[1] have so succinctly set forth in few words the diagnostic features of pure pulmonary stenosis that it seems worth while to quote verbatim:

From the Children's Memorial Hospital and Grant Hospital.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

1. Potts, W. J.; Gibson, S.; Riker, W. L., and Leininger, C. R.: Congenital Pulmonary Stenosis with Intact Ventricular Septum, J. A. M. A. **144**:8 (Sept. 2) 1950.

The symptoms and signs vary considerably from those encountered in the tetralogy of Fallot and tricuspid atresia. There may be dyspnea and marked decrease of exercise tolerance with relatively little cyanosis. The heart is enlarged. There is usually a systolic murmur, often accompanied with a thrill at the base of the heart. Pulsation of the liver is frequently present. The fluoroscopic and roentgenographic examinations reveal enlargement of the right ventricle. The lung fields are clear. Inasmuch as poststenotic dilatation of the pulmonary artery is usually present, the pulmonary artery segment is usually prominent. The electrocardiogram shows right ventricular hypertrophy with high, sharp P waves in lead 2. Cardiac catheterization reveals much increased pressure in the right ventricle with abnormally low pressure in the pulmonary artery. The angiocardiogram fails to show an overriding of the aorta. The dye remains abnormally long in the right ventricle.

The surgical treatment of pure pulmonary stenosis differs from that of the tetralogy of Fallot. In the latter satisfactory results are obtained by shunt operations between the subclavian and the pulmonary artery or the aorta and the pulmonary artery. However, in patients with valvular stenosis a shunt operation is apt to lead to excessive strain on the right side of the heart. Cyanosis may be relieved, but the shunt carries more blood to the lungs and thereby raises the pressure in the left auricle. Less blood can therefore escape from the distended right auricle through the patent foramen ovale, and right heart failure follows. The only reasonable operative approach in these patients therefore constitutes a direct attack on the stenotic valve itself, as first accomplished by Sellors [2] and Brock.[3]

VALVULOTOMES

Since the most satisfactory approach to the stenotic pulmonary valve is transventricular, first consideration must be given to the instruments by which this stenosis can be relieved. Sellors used a tenotomy knife in the first patient successfully operated on. Brock uses a sharp, diamond-shaped valvulotome on the end of which is a blunt guide point. After valvulotomy dilators are introduced and forced through the incised valve to assure adequate opening of the valve. Blalock and Kieffer [4] have employed the Brock instrumentarium in the surgical treatment of 19 patients with pure pulmonary stenosis.

In a previous communication [1] a simple valvulotome was described which had been used successfully on four patients with pure pulmonary stenosis. This instrument consists of a small cataract blade on a rounded shaft attached to an ordinary knife handle. The rounded shaft was made of such size that it would fill the opening in the wall of the right ventricle and thus prevent loss of blood. Although this valvulotome proved successful and yielded excellent results in four patients, it was feared that it might fail to relieve completely the obstruction in older patients with more rigid valvular stenosis.

To devise and construct instruments for incision and dilatation of the stenosed pulmonary valve, as with the Brock instruments, and still make a small opening in the wall of the right ventricle was a simple matter. The principles of the expanding blade used by urologists and of the adjustable esophageal dilator used by

2. Sellors, T. H.: Surgery of Pulmonary Stenosis: A Case in Which Pulmonary Valve Was Successfully Divided, Lancet **1**:988 (June 26) 1948.

3. Brock, R. C.: Pulmonary Valvulotomy for the Relief of Congenital Pulmonary Stenosis: Report of 3 Cases, Brit. M. J. **1**:1121 (June 19) 1948.

4. Blalock, A., and Kieffer, R. F., Jr.: Valvulotomy for the Relief of Congenital Valvular Pulmonic Stenosis with Intact Ventricular Septum: Report of 19 Operations by the Brock Method, Ann. Surg. **132**:496 (Sept.) 1950.

endoscopists were drawn on in devising an expanding valvulotome and dilator which were made for us by Mr. Bruno Richter (fig. 1).[5] The principle of the valvulotome is the same as that described by Bailey and others [6] for the relief of aortic stenosis. The valvulotome is so constructed that the blades can be retracted by means of a turn screw while the instrument is being thrust through the wall of the ventricle. A rather important feature is the gage which indicates exactly how widely the blades of the knife are being expanded while in the chamber of the right ventricle preparatory to the thrust through the stenotic valve. The dilator is built

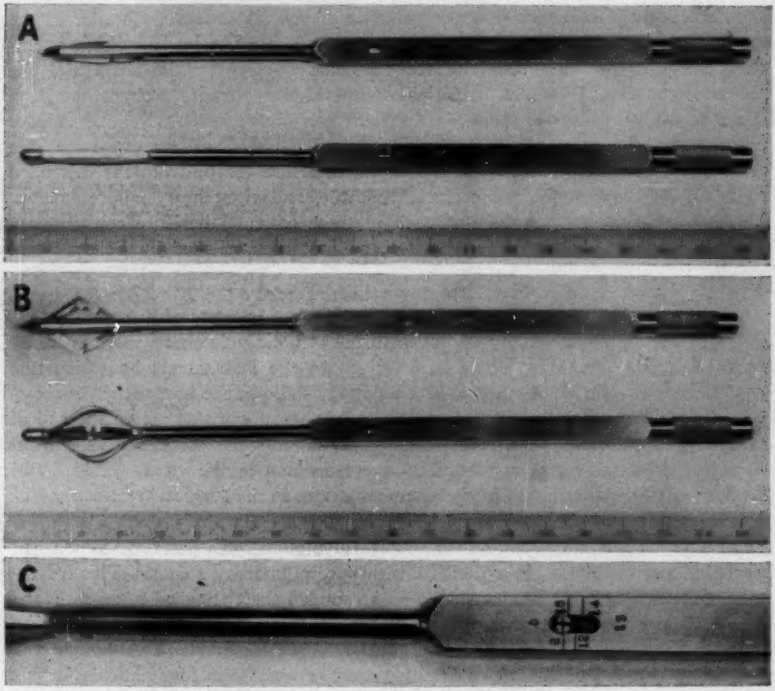

Fig. 1.—*A*, valvulotome and dilator closed. *B*, valvulotome and dilator opened. *C*, enlarged photograph of indicator.

on exactly the same principle. The shaft is the same caliber as that of the valvulotome and is introduced through the same hole in the right ventricle after the valvulotome has been withdrawn.

5. Bruno Richter, 843 Duane Avenue, Glen Ellyn, Ill.

6. Bailey, C. P.; Glover, R. P.; O'Neill, T. J. E., and Redondo Ramirez, H. P.: Experiences with the Experimental Surgical Relief of Aortic Stenosis: A Preliminary Report, J. Thoracic Surg. **20**:516 (Oct.) 1950.

THE OPERATION

Preoperative medication is given in rather liberal doses. For example, a 5 year old child receives morphine sulfate, ⅛ grain (8 mg.), and scopolamine hydrobromide, 1/200 gr. (0.3 mg.), one hour before operation. Such preoperative medication alleviates or abolishes the child's anxiety in coming to the operating room and reduces the amount of anesthesia, and Dr. William O. McQuiston, the anesthesiologist, believes it influential in reducing cardiac irregularities.

Cyclopropane with small amounts of ether during induction, preparatory to inserting the intratracheal tube, has been the anesthetic agent of choice. The patient is kept in the first plane of anesthesia during the entire operation.

A plastic tube or large needle is always inserted into the saphenous vein at the ankle for the administration of fluid and/or blood. There is available in the operating room 1,000 cc. of blood for a teen age child and 500 cc. for a 3 year old child. Normally only about one third of this blood is used. It is a pleasure to discard the balance if it cannot be returned to the bank.

A water mattress covered with double thickness sheeting is placed on the operating table. Through this mattress cool or ice water may be run during the operation to maintain the patient's temperature at normal or below normal levels. The more cyanotic the patient the further his temperature is reduced during the operation. In all severely cyanotic patients with all types of pulmonary stenosis the temperature is brought down to well below normal during the operation. The basis for this procedure is the well established fact that reduction of temperature lessens the rate of consumption of oxygen and thereby reduces the danger of disastrous anoxia. A thermocouple, inserted into the rectum, is attached to an illuminated galvanometer which allows continuous observation of the temperature. (A detailed report on temperature control during the surgical procedure will soon be published by Drs. John A. Bigler and William O. McQuiston.)

A curved submammary incision is made beneath the left nipple (fig. 2 *A*). The pectoralis major muscle is reflected upward and the chest entered through the third intercostal space (fig. 2 *B*). The second, third and fourth ribs are cut at the costosternal junction. Attempts are made to avoid the internal mammary artery but are rarely successful. A small opening is made in the pericardium and 5 cc. of 1 per cent procaine hydrochloride is introduced and left in the sac for about five minutes. The pericardium is then generously opened through a longitudinal incision anterior to and parallel with the phrenic nerve.

If the diagnosis of pure pulmonary stenosis is correct, one will see a large, round, tense, bulging right ventricle. Characteristic and diagnostic is poststenotic dilatation of the pulmonary artery. Constriction, apparent or real, will be visible in the pulmonary artery at the base of the heart at the site of the pulmonary valve. Palpation will convey to the finger a feeling of increased pressure in the right ventricle and decreased pressure in the dilated pulmonary artery. Blood rushing through the stenosed valve into the dilated pulmonary artery produces a palpable high-pitched systolic thrill. As the wall of the pulmonary artery is slightly compressed, a jet of blood can be felt as it is being forced through the constriction with each heart beat. These observations at the operating table are important. Low pressure in the right ventricle immediately proximal to the origin of the artery can only mean infundibular stenosis. Likewise, maximum intensity of the systolic thrill palpable over the ventricle rather than the site of the pulmonary valve means infundibular rather than pulmonary stenosis.

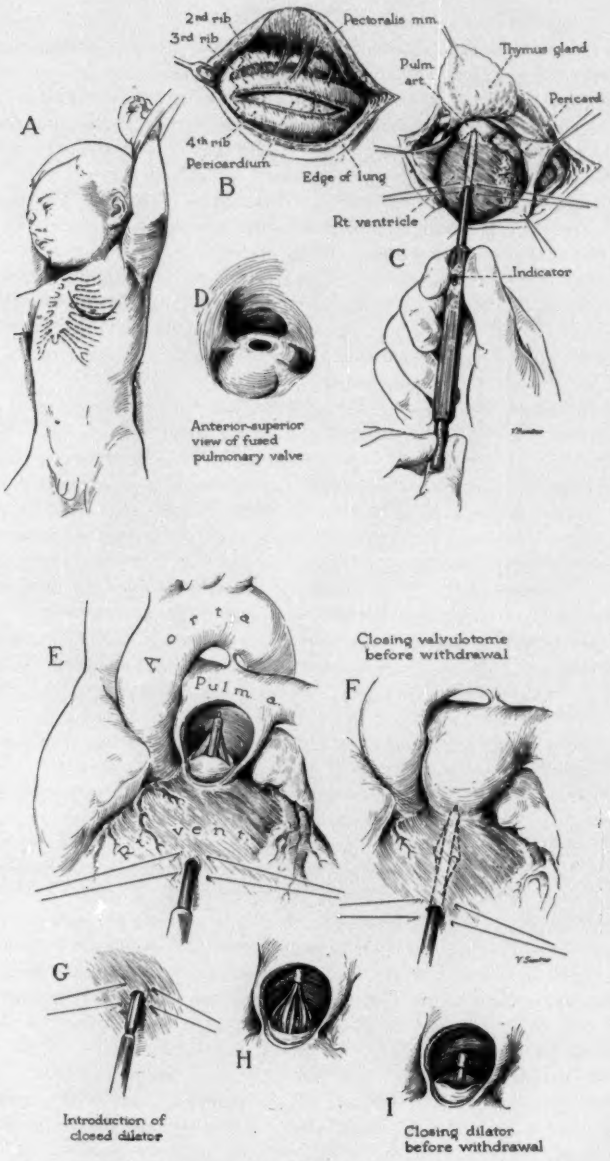

Fig. 2.—See description in text.

After the diagnosis of pure pulmonary stenosis is confirmed, 2 cc. of 1 per cent procaine is injected into the wall of the right ventricle at the site chosen for introduction of the valvulotome.

Two holding sutures of 0000 Deknatel silk on a curved swaged-on no. 44 needle are introduced into the wall of the right ventricle. With a sharp-pointed knife a tiny transverse incision is made part way through the musculature between the holding sutures. The valvulotome, completely closed and held in the right hand, is now thrust into the right ventricular chamber and guided to the stenotic valve by palpation with the left forefinger (fig. 2*C*). The approximate diameter of the constricted pulmonary artery is estimated by direct vision and palpation, the valvulotome opened to that size (fig. 2*E*), thrust through the fused pulmonary valve and withdrawn into the ventricular chamber (fig. 2*F*). One immediately feels increased pressure in the pulmonary artery and a larger jet of blood going through the vessel. The valvulotome is completely closed and withdrawn. Bleeding from the wound in the heart is controlled by pressure with the index finger until the closed dilator can be introduced. The dilator is directed to the site of the recently incised constriction and opened as widely as the caliber of the pulmonary artery will allow (fig. 2*G* and *H*). Haste is unnecessary during this maneuver because blood can flow through the ribbed dilator in the pulmonary artery while the dilatation is being done. The dilator is completely closed (fig. 2*H*). Just before its withdrawal from the heart a suture is put through the muscle wall close to the instrument and tied as the dilator is removed. A second stitch is placed next to the first. When all goes well little blood is lost. The pericardial sac is closed with interrupted silk stitches, leaving a fairly generous opening near the apex to prevent accumulation of fluid. The chest is drained through the fifth interspace, and the wound is closed in layers with running surgical gut.

COMMENT

No child with a diagnosis of pulmonary stenosis is denied operation, regardless of his condition.

During the past 10 months a total of 13 patients with pure pulmonary stenosis have been operated on. Their ages were as follows: 23, 39 and 60 days; 10, 12, 13, 15 and 20 months, and 2, 6, 10, 15 and 17 years. The average preoperative red blood count was 6,300,000 per cubic millimeter, approximately one million less than the average red blood cell count of patients with tetralogy of Fallot. With one exception cyanosis was visible in all patients. All but three of the patients had enlargement of the liver. Definite and unquestioned pulsation of the liver was found in only one of these patients.

Cardiac enlargement varied from slight to tremendous (see case report). Considerable enlargement of the heart, especially the right ventricle, however, is rather typical of pure pulmonary stenosis. All patients had a systolic murmur, the harshness of the murmur being inversely proportional to the severity of the patient's condition. Cardiac catheterizations, when done, uniformly showed high right ventricular pressure and low pulmonary pressure. Angiocardiograms were not routinely done. A number of patients were in such precarious condition that the procedure did not seem justifiable. While it is reassuring to see in the roentgenograms an intact interventricular septum and slow emptying of the right

ventricle, one must not trust the fleeting shadows of these roentgenograms too implicitly. Two patients not included in this series had a condition diagnosed clinically and roentgenographically as pure pulmonary stenosis, one at our hospital and the other at another cardiology clinic. At operation the ventricle was not distended, pressure in it was low near the origin of the pulmonary artery and the typical thrill over the pulmonary valve was absent. An aortic-pulmonary anastomosis was done in one and a subclavian-pulmonary anastomosis in the other, with satisfactory results but through a rather awkardly placed incision.

The technique of operation as described above is basic, but variations are in order as conditions demand. For example, one patient, a boy 6 years old, had a condition diagnosed as pure pulmonary stenosis with a suspicion of added infundibular stenosis. At operation there was palpable the typical spurt through the stenotic pulmonary valve but the right ventricle was not round and distended. In this patient the small cataract knife valvulotome was introduced in retrograde fashion through the wall of the left pulmonary artery into the stenotic valve in the main pulmonary artery. The valve was then expanded, with the dilator introduced through the same opening. This patient has lost all cyanosis and dyspnea and has gained 6 pounds (2.7 Kg.) during three months since operation.

In another patient, a child 10 months old and in precarious condition, the surgical technique varied somewhat from the routine. The small knife valvulotome was thrust through the ventricle and the stenotic valve quickly incised. The child promptly improved. Then the dilator was introduced through the same opening and the pulmonary valve completely expanded. The infant went through the operation very well. We are inclined to believe that such a procedure might be generally adaptable to infants and young children in a precarious condition. Introduction of the small valvulotome is nontraumatic and is quickly done, with little loss of blood. After this hasty procedure the patient is allowed a few minutes to improve and will do so because of increased oxygenation. Then the dilator may be introduced leisurely to make sure that dilatation is complete.

The one death in this series occurred on the operating table in a 13 month old child (S. L.) weighing 19 pounds (8.6 Kg.), who had a red blood cell count of 8,600,000, was unable to sit up and was subject to attacks of unconsciousness. The blood pressure was unobtainable even before the operation was begun. Immediately after the valvulotome was pushed through the pulmonary valve the heart stopped beating for a few minutes. After massage vigorous beating was suddenly resumed for probably less than a minute but then permanently ceased. At postmortem examination a typical pure pulmonary stenosis was found. It had been satisfactorily cut.

It is important, when putting the holding sutures in the ventricular wall, to take a large bite of muscle. It is equally important not to pull on these sutures too energetically. Too small a bite and too much tension on the sutures resulted in a tear of the cardiac muscle in one case, with rather frightening but not fatal hemorrhage.

There have been no postoperative complications of significance. It is poor etiquette to exclaim too vigorously about successes following any operation. However, the results following valvulotomy as advised by Sellors and Brock are often actually spectacular. To see cyanosis give way to normal color immediately after

incising the valve is, to say the least, gratifying. The following case report, although not truly representative of the average case, is illustrative of the pleasant surprises which occasionally follow operation on a seemingly hopeless patient.

D. J., a Negro female infant born Dec. 29, 1948, was admitted to the Children's Memorial Hospital on March 25, 1949, because of incarceration of the ovary in a right inguinal hernia. Except for irritability during the five weeks the hernia had been present, the infant's history to the time of her admission had been typical of a normally growing baby. An unusual sliding hernia of the ovary was corrected surgically without untoward incident. If there was a heart murmur at the time of admission, as there probably was, it was missed or not recorded. The red blood cell count was 5,100,000 and the hemoglobin value 14.9 Gm. per 100 cc. The mother offered no history of cyanosis or any other symptom referable to congenital heart disease.

The child was seen again on May 28, 1949, because of cough. At this time a loud systolic murmur was heard near the sternum in the third left interspace. The patient was referred to the outpatient cardiac clinic but failed to keep all appointments until August of 1949. At this time the red blood cell count was still 5,000,000 but the hemoglobin value had fallen to 10.9 Gm. There was no visible cyanosis or clubbing of the fingers. Roentgenograms showed clear lung

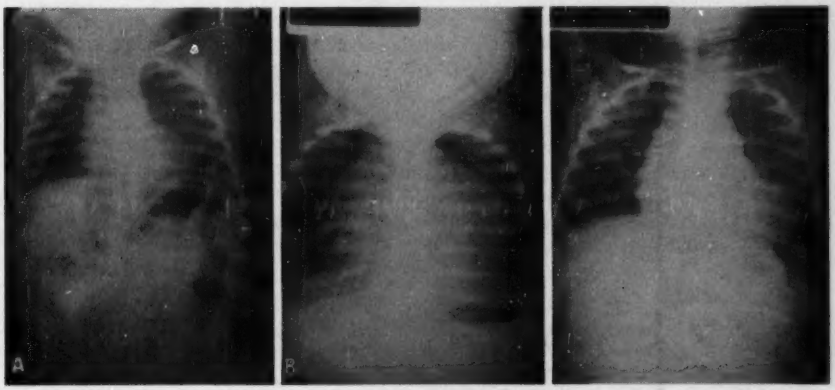

Fig. 3 (D. J.).—*A*, heart at age 7 months; *B*, heart at age 20 months; *C* heart two months after operation.

fields and a somewhat boot-shaped heart (fig. 3*A*). The electrocardiogram showed sinus tachycardia and right axis shift. A diagnosis of congenital heart disease, probably tetralogy of Fallot, was made by Dr. Stanley Gibson.

Again all appointments were not kept, and the child was not seen until March 1950 at the age of 15 months, when she was admitted to the hospital because of cough and labored respiration for two days. The red blood count was now 6,800,000. The liver edge was down 2 fingerbreadths below the costal margin. The heart murmur was as before. Roentgenograms still showed clear lung fields, but the heart had lost the concavity in the region of the right conus suggesting pure pulmonary stenosis. The electrocardiogram showed more heart strain and a peaked P wave, especially in lead II. Chickenpox developed, and the child had to be referred to another hospital.

She was readmitted in June 1950 with heart failure. The liver was 3 fingerbreadths below the costal margin, and there was pitting edema of the face, hands and legs. Pulsations of the liver were palpable. At fluoroscopic examination marked enlargement of the right auricle and ventricle was seen. The child was digitalized, improved during a two weeks' stay in the hospital and was given an appointment to return for angiograms. As usual the appointment was not kept, and on Aug. 4, 1950, the patient, now 20 months old, was again admitted to the hospital in heart failure. The red blood count was 6,000,000, but cyanosis was questionable. X-ray

examination of the heart now showed tremendous enlargement (fig. 3*B*). Pulsations of the liver were easily palpable. On digitalis therapy compensation was restored. The child could stand when supported but had never walked. Her weight before operation was 21 pounds (9.5 Kg.). Because of her poor condition it was felt that angiograms should not be done. The diagnosis of pure pulmonary stenosis seemed rather definite. Since the patient had no chance without surgical relief, operation was advised.

Operation was performed on Aug. 16, 1950. The technique described above was used. The pericardial sac contained an estimated 75 cc. of clear fluid. The valvulotome, expanded to 12 mm., was thrust through the stenosed valve. The dilator was extended in the pulmonary artery to 14 mm. in diameter. Immediately after incision of the stenosis with the valvulotome, pressure in the pulmonary artery rose, and instead of a jet of blood, a gush could be felt coming through the pulmonary artery.

The postoperative course was uneventful. Pulsations of the liver had disappeared within two weeks after operation. One month later the heart had decreased markedly in size (fig. 3*C*). The preoperative high-pitched systolic murmur became low-pitched after operation. The child is now completely asymptomatic, three months after operation.

SUMMARY AND CONCLUSIONS

Valvulotomy is a logical and relatively simple procedure for the relief of pure pulmonary stenosis. The operation requires about an hour, and most of that time is spent in opening and closing the chest. An expanding valvulotome and a dilator for this operation are described. Valvulotomy has been performed on 13 patients, with one death. Results have been excellent in 11 patients and fair in one. At the moment we believe that patients with tetralogy of Fallot are more safely treated by either a subclavian-pulmonary or an aortic-pulmonary anastomosis.

ATTEMPTS AT THE EXPERIMENTAL PRODUCTION OF PORTAL HYPERTENSION

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VON ECK [1] first produced a portacaval fistula in dogs in 1877, and he performed eight such operations. In this operation the portal vein was ligated between the anastomosis and the liver. Other reports since this time by Pavlov,[2] Freeman [3] and others have indicated that a fistula produced in this manner will remain patent. In our hands the production of such a fistula in the dog without portal obstruction results in closure of the fistula in approximately one third of the cases in three to six weeks. It seemed important to produce chronic portal hypertension in dogs to determine whether a similar frequency of closure occurred in the portacaval fistulas before applying the procedure to human beings. Chronic portal hypertension has been produced by Kershner, Hooton and Shearer [4] in the dog by partial obstruction of the inferior vena cava. This procedure was not applicable in our experiments, since it was desired to determine the effect of a portacaval anastomosis after development of the hypertension.

As far as we have been able to learn from the literature, chronic portal hypertension without interruption or impairment of the caval system has been produced experimentally in the dog only by Rousselot and Thompson.[5] They produced cirrhosis of the liver with splenomegaly and submucosal esophageal varices by the injection of silicon dioxide into the splenic vein. This process requires at least 18 to 37 months. A shorter method was desired.

We have attempted to produce a chronic increase in portal pressure by partial occlusion of the blood vessels entering and leaving the liver. All portal pressures were taken by means of a water manometer in dogs in the supine position anesthe-

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Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

From the department of Surgery, Northwestern University Medical School and Passavant Memorial Hospital.

1. Von Eck, N.: Voyenno-Med. J. **130**:1, 1877.

2. Hahn, M.; Massen, O.; Nencki, M., and Pavlov, J.: Arch. exper. Path. u. Pharmakol. **32**:161, 1893.

3. Freeman, S.: Personal communication to the authors.

4. Kershner, D.; Hooton, T. C., and Shearer, E. M.: Production of Experimental Portal Hypertension in Dog: Anatomy of Hepatic Veins in Dog, Arch. Surg. **53**:425 (Oct.) 1946.

5. Rousselot, L. M., and Thompson, W. P.: Proc. Soc. Exper. Biol. & Med. **40**:705, 1939.

tized with intravenous injection of pentobarbital sodium. Normal pressure varied from 10 to 15 cm. of water. In nine healthy mongrel dogs, a Goldblatt clamp was placed on the portal vein near the hilus of the liver so as partially to occlude its lumen. This occlusion was done grossly by noting the color of the bowel. At the same time the hepatic artery was partially occluded by a Goldblatt clamp to impair liver function further and promote the chronicity of any changes.

There was no increase in portal pressure two to six weeks later when the animals were examined. There was no dilatation of the portal vein, and an adequate collateral venous circulation was present. In two of these animals the Goldblatt clamp on the portal vein was tightened at a second operation 15 to 25 days later so as to occlude the portal vein completely. This procedure resulted in no disturbance to the animal, and the pressure in the portal vein was not increased. These findings confirm those of Solowieff,[6] Neuhof,[7] and Brunschwig, Bigelow and Nichols[8]; the portal vein can be completely occluded if a staged procedure is carried out. Microscopic sections of the liver in these cases showed a marked fatty

TABLE 1.—*Partial Occlusion: Portal Vein Pressure (Cm. of Water)*

Animal	Preliminary Pressure	After Clamping	Result	Pressure, 3 mo.	Pressure, 6 mo.
1	10.1	20.5	Died after 24 hr.	....	....
2	15.0	28.5	Died after 16 days	....	....
3	12.5	28.0	Died after 24 hr.	....	....
4	14.0	29.0	Survived	15.2	....
5	9.0	19.5	Survived	14.0	....
6	20.0	34.5	Survived	21.0	....
7	13.5	25.0	Survived	18.0 *	14.5

* Clamp completely closed at 3 months.

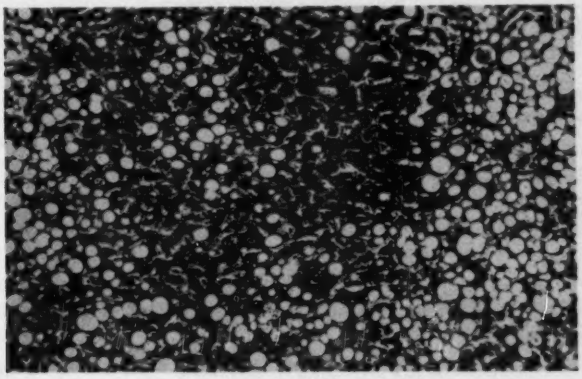
infiltration. Rich and others[9] believe such changes in the liver to be a precursor of portal cirrhosis.

In the next group of six animals only the portal vein was occluded partially by a Goldblatt clamp. All these animals died promptly. Because we had not accurately measured the amount of portal occlusion, it seemed probable that the occlusion was too severe and that the animals had succumbed to the blood volume loss characteristic of dogs in which the portal vein has been completely occluded.

In a third group of seven dogs the Goldblatt clamp was placed on the portal vein and tightened until the portal pressure had been doubled (table 1). Three of these animals died within 24 hours, their deaths suggesting that this amount of portal obstruction is close to the limit which can be tolerated by the dog. One of the animals died in 16 days with marked omental congestion but with only moderate mesentric engorgement. The cause of death was not determined. Exploration in the remaining three animals three months later revealed a relatively normal portal pressure. A portacaval anastomosis performed on the animals produced a drop below the normal portal pressure (3 to 14.5 cm.).

6. Solowieff, A.: Arch. path. Anat. **62**:195, 1875.
7. Neuhof, H.: Surg., Gynec. & Obst. **16**:481, 1913.
8. Brunschwig, A.; Bigelow, R., and Nichols, S.: Surgery **17**:781, 1945.
9. Rich, A. R.; Berthrong, M., and Germuth, F. G.: Tr. A. Am. Physicians **61**:262, 1948.

Although it has been reported by Ore,[10] Shiff [11] and Bernard [12] that the dog cannot survive complete occlusion of the portal vein, the work of Child, Milner, Holswade and Gore [13] on the survival of the Macaca mulatta monkey after sudden complete ligation of the portal vein stimulated us to try the results of this procedure in the dog. Kershner, Hooton and Shearer [4] have reported that some animals in which the inferior vena cava had been ligated died of a Clostridium welchii infection. One of us (Tanturi) also believed that anaerobic infections might play some part in the mortality of portal obstruction. In five dogs which had received 300,000 units of penicillin on the morning of the operation the portal vein was completely occluded by two silk ligatures. The portal pressures in these animals varied from



Photomicrograph of section of liver three months after partial obstruction of portal vein and hepatic artery showing marked fatty infiltration. Hematoxylin and eosin; × 210.

TABLE 2.—*Complete Occlusion: Portal Vein Pressure (Cm. of Water)*

Animal	Pressure After Ligation	Result
1	....	Death while under anesthesia; marked portal engorgement
2	30.0 plus	Killed in 5 days; pancreatic branch not ligated; pressure, 28.8
3	52.8	Died from hemorrhage
4	16 (?)	Died in 16 hours; engorgement
5	35.2	Died in 16 hours; engorgement

30 to 52.8 cm. of water after occlusion of the vessel (table 2). One animal died on the operating table as a result of uncontrollable hemorrhage during the measurement of the portal pressure. Three dogs died within 24 hours with splanchnic congestion. This confirms the findings of Elman and Cole [14] and Boyce,[15] who

10. Ore, M.: Compt. rend. Acad. sc. **42**:497, 1856.

11. Shiff, M.: Zentralbl. med. Wissensch. **8**:115, 1863.

12. Bernard, C.: Leçons sur le diabète et la glycogenèse animale, Paris, J. B. Baillière et fils, 1877.

13. Child, C. G.; Milner, R. F.; Holswade, G. R., and Gore, A. L.: Ann. Surg. **132**:475, 1950.

14. Elman, R., and Cole, W. H.: Hemorrhage and Shock as Causes of Death Following Acute Portal Obstruction, Arch. Surg. **28**:1166 (June) 1934.

15. Boyce, F. F.: The Rôle of Liver in Surgery, Springfield, Ill., Charles C Thomas, Publisher, 1941, chap. 10.

found that death in these animals is due to loss of effective circulating blood volume. The fifth animal was killed five days later to determine the cause of survival. It was found that a small pancreatic branch had been missed and that this had become enormously dilated. The pressure at this time was 28.8 cm. of water. This was not believed to be significant, since the dog was killed 5 days after operation and collateral circulation had not had time to develop.

In a fifth series of animals attempts were made to increase portal pressures by ligation or clamping of the main hepatic vein as it enters the inferior vena cava just under the diaphragm. This procedure failed to produce any signs of cirrhosis, increased portal pressure or varicosities. Portal pressures after as long as five months were normal. This fact substantiates the findings in the small series of Kershner, Hooton and Shearer.[4]

SUMMARY AND CONCLUSIONS

Complete sudden portal occlusion is uniformly fatal in the dog, and penicillin did not protect the animals in our experiments. Death is apparently due to loss of effective circulating blood volume.

Partial portal occlusion in the dog sufficient to double the portal pressure is fatal in about one half of the animals and causes the development of collateral circulation in 15 to 25 days in those which survive. Chronic portal hypertension, ascites or notable varices do not develop in the latter.

After development of collateral circulation, the portal pressure returns to a normal level, and the portal vein may then be completely occluded without the occurrence of death of the dog.

Obstruction of the main hepatic vein has failed to produce chronic portal hypertension.

PORTAL HYPERTENSION

Use of Venous Grafts When Side to Side Anastomosis Is Impossible

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THE ORIGINAL operation of portacaval shunt was first successfully carried out by von Eck in 1877.[1] Since that time, sporadic operations have been performed,[2] but results were discouraging and the operative death rate prohibitive. Today this operation may safely be recommended for properly selected patients.[3] Advances in anesthesiology have contributed much to the safety of this procedure, and adequate administration of blood and fluid, preoperatively, postoperatively and more particularly during the operative procedure, have further secured that

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Dr. Reynolds is from the Department of Surgery, University of Illinois College of Medicine, and the Fourth Surgical Service, St. Luke's Hospital and Dr. Southwick is a Research Fellow in Surgery, Presbyterian Hospital.

1. von Eck, N.: Kvoprosu o perevyazkïe vorotnoï veni (On the Ligation of the Portal Vein.), Voyenno-Med. J. **130**:1, 1877.

2. Lenoir, cited by Enderlen, H., and Magnus-Alsleben: Die Pathologie und Therapie des Pfortaderverschlusses. Experimentelle Untersuchungen über die Ecksche Fistel, Ztschr. f. d. ges. exper. Med. **3**:263, 1914. de Martel, R.: Summary of Technic of Eck's Operation, Rev. de chir. **42**:1181, 1910. Rosenstein, P.: Über die Behandlung der Lebercirrhose durch Anlegung einer Eck'schen Fistel, Arch. f. klin. Chir. **98**:1082, 1912. Vidal, E.: Discussion of Eck's Operation, Rev. de chir. **42**:1181, 1910.

3. (*a*) Blalock, A.: The Use of Shunt or By-Pass Operations in the Treatment of Certain Circulatory Disorders, Including Portal Hypertension and Pulmonic Stenosis, Ann. Surg. **125**: 129, 1947. (*b*) Julian, O. C., and Metcalf, W.: Nonobstructive Lateral Portal Vein-Vena Cava Anastomosis: A Clinical Application of the Smith Freeman Clamp, Arch. Surg. **59**:433 (Sept.) 1949. (*c*) Linton, R. R.: Surgical Treatment of Bleeding Esophageal Varicosities by Portal Systemic Venous Shunts, with a Report of 34 Cases, Ann. Int. Med. **31**:794, 1949. (*d*) Hardy, I. B., Jr., and Volwiler, W.: Portacaval Shunts in Treatment of Portal Hypertension.: Analysis of 15 Cases with Special Reference to Suture Type of End-to-Side Splenorenal Anastomosis with Splenectomy and Preservation of the Kidney, Surg., Gynec. & Obst. **87**:129, 1948. (*e*) Mahoney, E., and Hogg, H. L., Jr.: Congenital Stricture of the Portal Vein, Arch Surg. **61**:713 (Oct.) 1950. (*f*) Whipple, A. O.: Problem of Portal Hypertension in Relation to Hepato-Splenopathies, Ann. Surg. **122**:449, 1945. (*g*) Welch, C. S., and Sears, B. R.: Thoracolumbar Approach for Portacaval Anastomosis: Technique in Experimental Animals; A Preliminary Report, Bull. New England M. Center **9**:71, 1948. (*h*) Welch, C. S.: A Technique for Portacaval Anastomosis (Eck Fistula), Surg., Gynec. & Obst. **85**:492, 1947. (*i*) Blakemore, A. H.: Portacaval Anastomosis for Portal Hypertension, Surgery **26**:99, 1949. (*j*) Blakemore, A. H., and Lord, J. W.: Blood Vessel Anastomosis by Means of a Non-suture Vitallium Tube Method, in Andrus, W. DeW.: Advances in Surgery, New York, Interscience Publishers, Inc., 1949, p. 337.

safety. Proficiency in the execution of anastomoses between delicate and friable veins is essential, and the surgeon must master these skills in the experimental laboratory before attempting to perform the procedures in human beings.

The two cases presented in this report are illustrative of some of the technical difficulties which may be encountered in attempting to perform a portacaval shunt.

REPORT OF CASES

Case 1.—E. B. (St. Lukes, no. 147885), age 42, entered the hospital on March 27, 1950, with a diagnosis of cirrhosis of the liver with portal hypertension and ascites. Esophageal varicosities had been demonstrated roentgenologically, and he had had severe hematemesis in January 1950. He presented the typical picture of advanced cirrhosis, with spider telangiectasis on the face, emaciation and protuberant ascitic abdomen.

For 12 years previous to his admission he had been a heavy drinker (up to a quart [1,000 cc.] a day) and had eaten poorly. Since 1947 he had undergone 30 paracenteses, which yielded from 4 to 12,000 cc. at each tapping. Jaundice, nausea or vomiting had never been present. He had moderately severe laryngitis.

Laboratory Data.—On the patient's admission the red blood count was 3,560,000 per cubic millimeter, the hemoglobin 10.2 Gm. per 100 cc., and the white blood count 5,100 per cubic millimeter. The nonprotein nitrogen was 29 mg. per 100 cc., the blood sugar 126 mg. and the thymol turbidity 8.0 units. The phosphorus level was 3.6 Bodansky units; alkaline phosphatase 7.1 Bodansky units; total quantitative bilirubin 0.63 mg. per 100 cc., with immediate value 0.16 mg. and indirect value 0.47 mg.; total proteins 7.17 Gm. per 100 cc., with albumin 1.67 Gm. and globulin 5.46 Gm., and the prothrombin time 33 seconds (normal, 30 seconds). The urine was negative for albumin and sugar; the specific gravity was 1.021 and the pH 6.5. The Kahn reaction was doubtful and the Wassermann reaction weakly positive. The sulfobromophthalein test gave the following results: in 50 seconds 18.6 per cent was still circulating and in 60 seconds 15.0 per cent. The phenolsulfonphthalein test showed that in the first specimen 45 per cent was excreted and in the second 20 per cent. The hematocrit value was 33. The mean corpuscular volume was 92.4 cubic microns and the mean corpuscular hemoglobin 29.4 micrograms.

On April 11, 1950, the Wassermann and Kahn tests gave negative results. The heparin protamine titration revealed an excess of 1.668 units of heparin or heparin-like substances per cubic centimeter of plasma.

Operation.—After treatment of the patient's laryngitis, he was operated on, April 13, 1950. A right thoracoabdominal approach was used, the hilus of the liver exposed and the portal vein and vena cava dissected. It was evident at once that direct anastomosis would be impossible, since there was a large nodule (about 3 by 3 by 3 cm.) of regenerated liver protruding between the portal vein and the vena cava (fig. 1*C*). This nodule had to be removed in order to assure a place through which a venous graft might travel. The azygos vein, which was readily accessible through the thoracic portion of the exposure (fig. 2), was removed from its junction with the superior vena cava for a distance of about 5 cm. It was 1.5 to 1.75 cm. in diameter and free of valves. This segment had to be shortened somewhat before it was inserted between the vena cava and the portal vein. Both of these procedures were carried out, with the use of Southwick clamps to secure a bloodless segment of recipient vein (fig. 2) and meticulous care to insure an intima to intima anastomosis. After the clamps were removed the blood could be seen swirling from the portal lumen into the caval lumen. Initial pressure reading in the portal vein was 380 mm. of water; subsequently, it was 310 mm. The pressure in the vena cava was 120 mm. and in the graft proper 180 mm. of water.

The postoperative course was satisfactory except for a persistent amount of tracheal secretion, and the presence of large amounts of pleural fluid on the right side. The patient was given food orally on the third postoperative day and was out of bed.

The postoperative laboratory data were as follows: On April 14, 1950, the red blood count was 4,100,000 and the white blood count 10,500. The urinary albumin was 20 mg. per 100 cc. On April 15, 1950, the serum chloride level was 515 mg. per 100 cc., the carbon

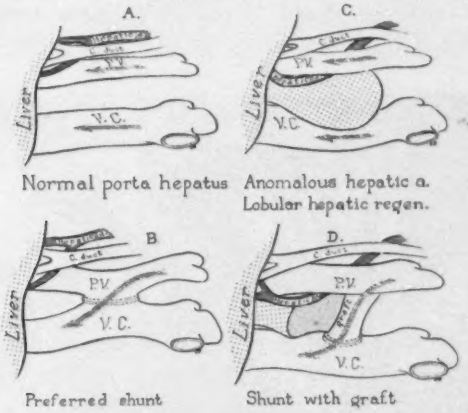

Fig. 1.—Conventional and alternative portacaval shunt. *A*, normal porta hepatis. *B*, preferred shunt. *C*, note the aberrant hepatic artery between the portal vein and the vena cava. Also note the regenerated liver lobule which separates these veins. *D*, anastomosis completed by means of a graft. Note how this is possible in the presence of the aberrant artery and after the removal of the obtruding liver nodule.

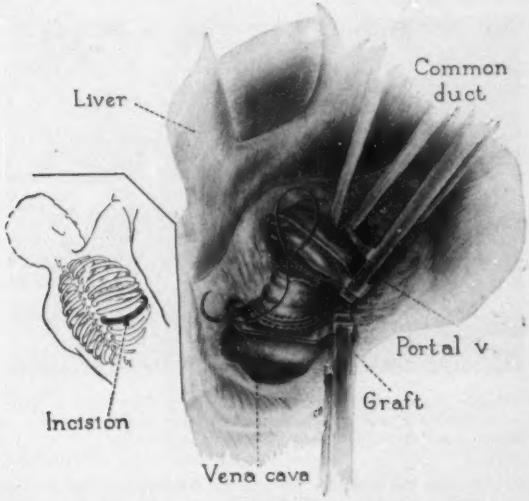

Fig. 2.—Portacaval shunt. Note the special Southwick clamps which allow maintenance of normal blood flow in both veins. Note also care with which the intima-to-intima technique is carried out.

dioxide-combining power 72.1 volumes per cent and the nonprotein nitrogen 44 mg. per 100 cc. On April 16, 1950, the red blood count was 3,500,000 and the white blood count 11,250. The

serum chloride level was 525 mg. per 100 cc. and the carbon dioxide-combining power 68.3 volumes per cent. On April 19, 1950, the quantitative bilirubin test gave a total value of 4.1 mg. per 100 cc., with the immediate value 1.4 mg. and the indirect value 2.7 mg. The prothrombin time was 66.6 per cent, and the pleural fluid had a specific gravity of 1.011. On April 21, 1950, the quantitative bilirubin test gave a total value of 5.8 mg. per 100 cc., with the immediate value 22 mg. and the indirect value 3.6 mg. The prothrombin time was 73.1 per cent.

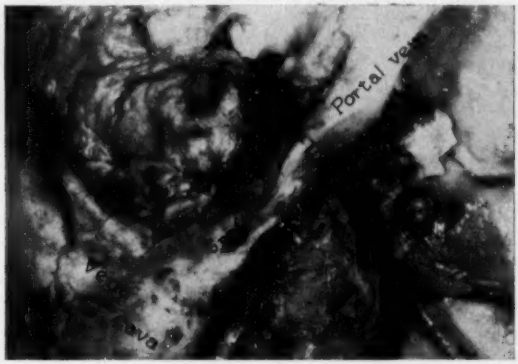

Fig. 3.—Photograph of autopsy specimen showing the free graft between the vena cava and the portal vein.

Fig. 4.—Photograph of same specimen as that in figure 3. Vena cava is opened, showing the stoma at the junction with the graft. Note that there is no visible fibrin on the patent stoma through which a probe protrudes.

Ten days after operation the patient walked to the lavatory unaided at midnight. He did not arise the next morning (April 23) and was recognized as being in coma at 8:00 a. m. His blood pressure was 50 systolic, diastolic pressure unknown. On thoracentesis, 1,800 cc. of serosanguineous fluid was recovered; 500 cc. of plasma was given and the blood pressure was 80/50 and the pulse rate 80. There was thick mucus in the trachea which was blood tinged. Tracheotomy at that time was not advised. At noon the blood pressure was unobtainable, and although a tracheotomy was done, it did not prevent death.

Postmortem examination showed cirrhosis of the liver. There was moderate bilateral hydrothorax, with some blood-tinted mucus in the trachea and bronchi; the portacaval shunt was open, and there was no thrombosis at either anastomotic site (figs. 3 and 4). The amount of fibrin deposited about the operative site seemed to be no more than that expected.

The coma into which this patient lapsed was unnoticed by the other men in the ward, who had thought he was sleeping. The increase in the quantitative bilirubin in studies recorded between April 19 and April 21 was suggestive of liver failure (despite his having been up and about at midnight).

Case 2.—R. W. (Research and Educational Hospitals, no. 354-415) aged 24, had been under study in the clinic because of repeated hemorrhages from her esophagus. While visiting in another city, she was subjected to a splenectomy (September 1949). On her return she had another bout of hemorrhage. Careful study here included esophagoscopy and roentgenograms of the esophagus, which proved beyond doubt that the bleeding came from the esophagus. She was readmitted to the hospital for a portacaval shunt operation.

Laboratory Data.—Urinalysis gave normal results. The red blood count was 2,200,000, hemoglobin 11 Gm. per 100 cc. and hematocrit 31. These values rose, until on March 16, 1950, the red blood count was 3,800,000, the hemoglobin 14 Gm. and the prothrombin time 92 per cent of normal. The cephalin flocculation time was 2 plus at 24 hours and 4 plus at 48 hours. The nonprotein nitrogen was 27 mg. per 100 cc., cholesterol esters 450 to 500 mg. per 100 cc. and inorganic phosphorus 3.0 Bodansky units. The icterus index was 24. The bilirubin value, indirect, was 1.8 mg. per 100 cc. Alkaline phosphatase was 17.4 Bodansky units. By the time the patient was operated on the cephalin flocculation time was 0 at 24 hours and 1 plus at 48 hours. The thymol turbidity was 9.5 and the prothrombin time 100 per cent.

Operation.—On March 29, 1950, we elected to attack the portal vein directly, since there was a good possibility that the splenic vein had already been occluded by thrombosis. A thoracoabdominal approach was used. The vena cava was found, and at first all attempts to find the portal vein failed. The hepatic artery was found, where it divided as it came from the celiac axis, but the entire right portion of the porta hepatis seemed to be replaced by fibrous tissue and small 2 to 3 cm. veins which were tortuous. Neither the common duct nor the portal vein could be found. However, when the entire structure of the porta hepatis was retracted and rotated anteriorly, a fairly large portal vein was seen to be present on the posterior surface of the porta hepatis. This vein was about the size of an index finger and coursed in a fairly normal position until it entered the liver. There was considerable tension in the vein, not only from internal pressure but apparently from the pull which was exerted on it between the liver and its origin in the abdominal structures. This tension was such that it was impossible to bring the portal vein and the vena cava together for a typical side to side portacaval shunt. We therefore decided to attempt to bridge the gap with a venous graft. In attempting to take a graft from a vein as large as possible, the azygos vein was removed from the junction with the vena cava for a distance of about 6 cm. Southwick clamps were applied to the vena cava and the portal vein, and an appropriate length of azygos vein was anastomosed between them. The pressure in the vena cava before the operative procedure was 110 mm. of blood and citrate and that in the portal vein 430 mm. After anastomosis, the portal pressure dropped to 340 mm. In spite of our serious attempt to make the anastomosis as large as possible, it was obvious at the conclusion of our operation that we could have (and should have) made the stoma at least 4 mm. larger.

Biopsy of the liver revealed typical cirrhosis. The patient remained in the hospital for two weeks, during which time her course was uneventful. Since leaving the hospital, she has had one episode in which the vomitus was observed to be blood tinged, presumably because of the acute alcoholic gastritis for which she was hospitalized.

COMMENT

For all practical purposes, portal hypertension is a result of either extrahepatic or intrahepatic portal vein obstruction and as such it is generally subdivided. Presumably thrombosis of the portal vein which heals with cavernous transformation of the major portal vein gives rise to the so-called extrahepatic portal

hypertension. (When this condition affects only the splenic vein, a general portal hypertension does not develop.) The intrahepatic type of obstruction is most commonly caused by cirrhosis of the liver. Such rarities as congenital portal vein occlusion are occasionally encountered.[8e]

Extrahepatic Portal Hypertension.—The portal vein in most cases of extrahepatic portal hypertension is no longer patent as a single large structure. It is often replaced by a network of veins which are presumed to have developed after portal vein thrombosis, and the resultant condition is referred to as cavernous transformation of the portal vein. The absence of liver damage and the replacement of the single portal vein (which, incidentally, is large enough for anastomotic purposes) by a spongelike rete of small veins are the two most outstanding anatomical characteristics of the extrahepatic type of portal hypertension. In these cases veins other than the portal must serve as channels whereby the trapped portal circulation may be diverted. The splenic vein is preferred, and at present it is anastomosed to the side of the renal vein if possible. As might be anticipated, patients with this type of hypertension are younger than those with the intrahepatic type, and since there is little or no liver damage, their general condition is likely to be good. Hence, there is little need to delay operation, once any existing anemic condition is corrected.

Intrahepatic Portal Hypertension.—Patients with portal hypertension of the intrahepatic type usually present strictly medical problems. Significant liver damage is a predominant and constant part of the picture, and most of these patients do not come to the attention of surgeons.

Surgical relief may be required either when the complication of massive hemorrhage from esophageal varicosities develops or when progressive wasting ascites appears (occasionally these two complications occur together). Both complications may not be mechanical in origin but rather may reflect hepatic decompensation. In such instances they are really not surgical problems, although they may appear to be so if the patient is not carefully studied. Since bleeding from hepatic hypoprothrombinemia may develop if the liver is so badly damaged that it cannot synthesize prothrombin, it is essential that a differential diagnosis be undertaken with care.[8j] Not only must the source of the blood be known, but if the bleeding can be proved to be independent of esophageal varicosities, it is essential to determine whether it occurs as a result of permanent or temporary inadequacy of the liver. Large doses of vitamin K along with an adequate liver regimen should result in cessation of bleeding and a return of the blood prothrombin time to normal or nearly normal values. (A patient whose liver is so badly damaged that it cannot synthesize prothrombin on this regimen is obviously no candidate for operation and is probably doomed.) In this way, unnecessary operations may be avoided,[4] and under such a regimen patients who seemed initially to be in great need of an operation may improve to the point at which surgical therapy is no longer indicated. It is possible for esophageal varicosities to be present without bleeding.

Massive Hemorrhage.—Massive hematemesis may be the presenting symptom. When it is impossible to exclude bleeding from gastric or duodenal lesions,

4. (*a*) Blakemore, A. H.: Preoperative Evaluation of Liver Function in Patients with Cirrhosis of the Liver, Surg., Gynec. & Obst. **89**:357, 1949. (*b*) Blakemore and Lord.[8j]

roentgenograms must be used for an accurate diagnosis, even while the patient is bleeding. Since this bleeding may not stop within a short time and may rapidly threaten life, active measures should be taken at once to stop it. Such routines as bed rest, sedation and adequate doses of vitamin K (20 to 100 mg.) should be standard, but in addition to these there are now available on the market several types of multiple-lumened balloon-covered tubes, so designed that they will distend the lower esophageal segment and compress the varicosities which are the source of the bleeding there (fig. 5).[5] It is obvious that these tubes are of no value if the bleeding is gastric or duodenal in origin. The tube remains in position because of the presence of a large lower balloon, which when inflated is larger than the cardioesophageal stoma. The tube is so placed that slight traction on it anchors the balloon against the stoma, allowing the larger so-called esophageal balloon,

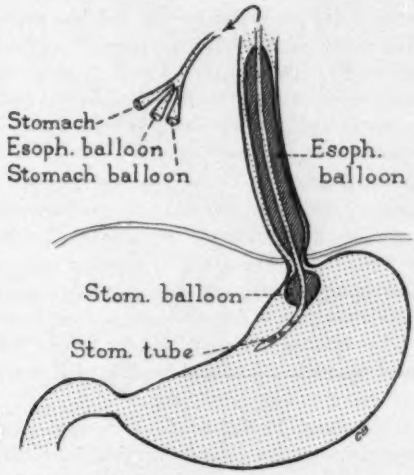

Fig. 5.—Diagram showing an esophageal tube in place. Note how with traction on the tube the gastric balloon serves to anchor the tube in the stomach, allowing distention of the esophageal balloon to compress the contents of the lower esophageal segment.

subsequently inflated, to compress the veins in the lower part of the esophagus. Bovine thrombin may be instilled into the lumen of the esophagus and allowed to trickle between the balloon and the esophageal wall.

This inflated tube probably should not be left in place for more than six hours, lest pressure ulceration develop. During this period the bleeding is stopped, the blood loss may be made up with the use of transfusions, and any residual blood may be aspirated from the stomach. After six to eight hours, the tube can be deflated slowly. A small amount of saline solution should be allowed to trickle down the esophagus, being either swallowed or instilled, for the purpose of lubrication.

5. Patton, T. B., and Johnston, G. G.: A Method for Control of Bleeding from Esophageal Varices, Arch. Surg. **59**:502 (Sept.) 1949. Sengstaken, R. W., and Blakemore, A. H.: Balloon Tamponage for the Control of Hemorrhage from Esophageal Varices, Ann. Surg. **131**:781, 1950.

The tube should be withdrawn gently.[5] We have had cases in which the balloon had to be used several times, and in one patient bleeding recurred so consistently after removal of the tube that an esophagectomy was necessary.

After the tube has been removed, the patient can be given the proper diet, which, if possible, should contain 200 Gm. of protein per day, be low in fat and salt content and be as nearly liquid as possible. This regimen will allow recovery of protein loss. The length of time which should elapse before surgical intervention in such cases is difficult to assess, but usually the fear of a subsequent hemorrhage (plus the fact that roughly 50 per cent of patients with cirrhosis who have massive bleeding will be dead within 18 months[6]) leads to fairly early surgical intervention.

Wasting Ascites.—Patients with wasting ascites are rare, yet occasionally they are candidates for the procedure described. Since the indications for the operation in this group of patients are much less precise and less urgent, and since these patients stand surgical intervention much more poorly than do those who undergo it for bleeding, they require especially careful study.[4a] In general, it may be said that when the patients are able to synthesize albumin (as indicated by retention of fairly adequate albumin and globulin levels in spite of repeated tapping) they should be able to tolerate the operation.[3j]

Since this group of patients are endangered not only by their liver disease but also by their ascites, care must be taken to give adequate liver treatment. Proper interpretation of a "liver condition" is difficult. There is a great deal of evidence to indicate that improvement of liver function may proceed slowly and indeed may continue unrecognized until the gradual disappearance of ascites becomes apparent. This evidence of improvement in liver function has manifested itself after three to six months of treatment, and for this reason we feel that when an operation is needed for ascites it should be delayed if possible for that length of time with the patient on a proper dietary regimen.[4]

Pathological Anatomy and Variations in Technique.—Patients with portal hypertension are poor risks, do not tolerate surgical intervention well and often can undergo only one operation. It is conceivable that they may tolerate operation provided a shunt is accomplished, whereas they will not recover if the shunt is not accomplished. It is therefore essential that the side-circuiting procedure be executed if at all possible. Since it may be necessary to abandon one proposed technique in favor of an alternative one, the surgeon must be familiar not only with the approach and the method of carrying out various procedures but also with all the variations in pathological anatomy which may be encountered in patients. In this way, he will be able to modify the technique so that a shunt is carried out.

The technical skill required to carry out anastomoses should be acquired by means of animal experimentation. The structures which must be sutured are veins, which are delicate and extremely friable. Furthermore, any technical error may destroy them, the only structure available. Experience and skill in the use of vein grafts are essential.

6. Capps, R. A.: Personal communication to the authors.

Proper exposure of the operative field requires the use of the combined thoracoabdominal incision,[7] which on the right exposes the portal vein and the vena cava as well as the azygos vein and on the left exposes the spleen, kidney and, when necessary, the esophagus and stomach.

Such congenital anatomical variations as the following have been encountered: The hepatic artery may course to the liver in a position dorsal to the portal vein (see fig. 1), thus occupying the space between the porta and the vena cava.[8] Double splenic veins or double portal veins may be so small in diameter that they are not large enough to be of value in carrying adequate amounts of portal blood. In one patient the vessels could not be brought together (see fig. 1, case 1).

Changes which result from the disease itself may also occur; peritoneal thickening may result in plaques. These plaques, present over the vein wall

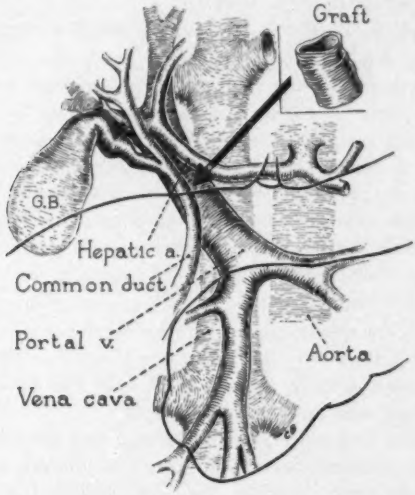

Fig. 6—Drawing of the structures at the porta hepatis. Note the short distance where the portal vein and the vena cava approach each other (heavy arrow). At this point an anastomosis with or without a graft may be constructed. The under surface of the liver and the upper border of the pancreas (which limit the area in which the portal vein can be freed) are indicated in heavy overlying black lines.

and actually a part of it, prevent adequate dissection of vein for anastomotic purposes. We have encountered two such cases. In each patient only a 1 cm. segment of vein could be exposed. This was barely large enough to use in association with a vein graft.

We have encountered one patient (case 1) in whom regeneration of the liver had occurred in such a way that a mass of tissue separated the veins (fig. 1).

7. Heaney, J. P., and Humphreys, G. H., II: Right Thoraco-Abdominal Approach, Ann. Surg. **128**:948, 1948. Carter, B. N., and Helmsworth, J. A.: Some Observations on the Use of the Combined Thoracico-Abdominal Incision, Ann. Surg. **131**:687, 1950. Linton.[3c] Blakemore.[3i,j]

8. Puestow, C. B.: Personal communication to the authors.

Type of Operation.—In deciding on the proper method to be used for carrying out a portacaval shunt, it should be pointed out that the simplest technical procedure is to divide the portal vein in the hilus of the liver and turn it down to implant it into the side of the vena cava. This operation will deprive the liver of all the portal blood flow (which makes up 75 per cent of the liver blood) and of much nutriment. At the same time, it delays the process of detoxification of the intestinal blood. The recent experiments of Large [9] and his associates (reported in this issue of the ARCHIVES) demonstrate that an animal whose portal blood has been totally diverted into the vena cava can withstand only small amounts of carbon tetrachloride poisoning, whereas animals in which a side to side anastomosis has been carried out tolerate almost as much carbon tetrachloride as do normal dogs. These results are so conclusive that there seems no excuse for the operation of anastomosis of the end of the portal vein to the side of the vena cava.

If a side to side portacaval shunt is to be effective in lowering the portal pressure, the stoma should have a diameter as nearly that of the portal vein as possible. The portal vein itself is short, frequently does not lie directly alongside the vena cava and must be mobilized, usually throughout its extent, in order to bring it to the side of the vena cava without tension. In the same way, the vena cava must be freed from its bed. Since the level at which the anastomosis must be carried out is usually at or just above the level at which the renal veins join the vena cava, this procedure is both tedious and possibly dangerous. Furthermore, the distance along which the portal vein and the vena cava lie near to and more or less parallel to each other is limited cephalad by the liver and caudad by the head of the pancreas (fig. 4).

It is particularly important to carry out an anastomosis in which the intima to intima principle is respected (fig. 2). Since blood flow through veins is less rapid than that through arteries, there is much more likelihood of clot formation if any part of the anastomotic site is made up of the cut end of a vessel wall. Obviously, a bloodless field is temporarily essential, and this can now be obtained by clamps especially designed for the purpose.[10] The older method of isolating the field by ligatures totally occludes the blood flow in the vessels concerned, whereas the clamps isolate only a segment of vein wall, allowing normal blood flow in the rest of the vein. When the factor of haste is eliminated, the operation can be carried out with requisite care and precision.

It is obvious that either a side to side portacaval shunt or an end to side splenorenal shunt should be done. When there is any doubt of the availability of the splenic vein, the portacaval shunt is preferable, since the portal vein is usually larger. When it is thought that splenic disease is a significant factor, splenectomy with splenorenal shunt should be kept in mind (fig. 7). The use of the femoral or azygos veins as sites for possible grafts should also be considered.

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9. Preshaw, D. E.; Large, A. M., and Johnson, A. F.: Effect of Portcaval Venous Shunt on Sulfobromophthalein (Bromsulphalein®) Retention, A. M. A. Arch. Surg., this issue p. 801.

10. Southwick, H. W.: A Clamp for the Construction of Vascular Anastomoses, Arch. Surg. **60**:372 (Feb.) 1950.

Attempts at lowering the portal pressure by diversion of part of the arterial inflow into the portal area have been made. Everson and Cole [11] Blain and Blain [12] and Moore, Singleton and Pickett [13] have tied off the splenic artery. This approach has been extended by the experimental work of Dock [14] and that of Berman,[15] who has ligated the hepatic artery and the splenic artery at the celiac axis. In such a procedure there is a drop in portal pressure of some 60 per cent. It is too early to say whether or not this work (and the occasional clinical trials which have been made by Berman) will find a place in the therapy.

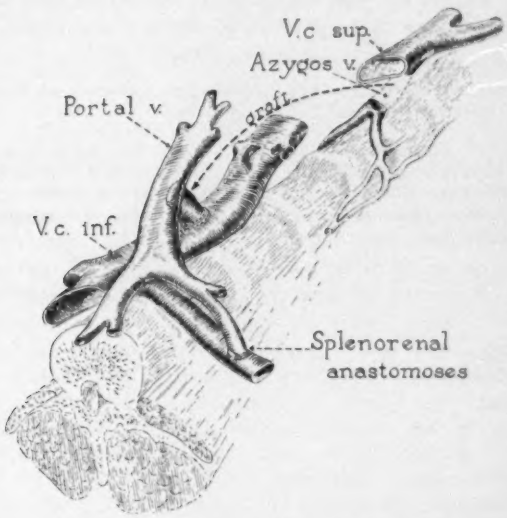

Fig. 7.—Drawing to show the source of a venous graft taken from the azygos vein. Note that it is taken as near the superior vena cava as possible. This drawing also shows the completed portacaval and splenorenal anastomoses. While they are not to be done on the same patient, they illustrate the side to side principle.

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11. Everson, T. C., and Cole, W. H.: Ligation of the Splenic Artery in Patients with Portal Hypertension, Arch. Surg. **56**:153 (Feb.) 1948.

12. Blain, A. W., and Blain, A., III: The Ligation of the Splenic Artery, the Operation of Choice in Selected Cases of Portal Hypertension and Banti's Syndrome, Ann. Surg. **131**:92, 1950.

13. Moore, R. M.; Singleton, A. O., Jr., and Pickett, W. H.: Splenic Artery Ligation in the Palliation of Ascites, Ann. Surg. **131**:774, 1950.

14. Dock, W.: Role of Increased Hepatic Arterial Flow in Portal Hypertension of Cirrhosis, Tr. A. Am. Physicians **57**:302, 1942.

15. Berman, J. K.; Koenig, H., and Saint, W. K.: Ligation of the Hepatic and Splenic Arteries in the Treatment of Portal Hypertension: Preliminary Report, Quart. Bull. Indiana Univ. M. Center **12**:99, 1950.

In order to complicate the picture of this disease further, there are those who feel that no shunt operation should be done for bleeding but rather that esophagectomy with preservation of the high portal pressure (which is presumed to be essential to continued liver function) is the operation of choice.[16]

SUMMARY

Two cases of portal hypertension are presented in which portacaval shunts were accomplished. They are unique in that the shunt was accomplished by the use of a segment of azygos vein as a free graft. The distance between the veins was such that without the graft the operation would have been impossible. A short discussion of some of the problems encountered is presented.

900 N. Michigan Avenue (Dr. Reynolds) Chicago 11.

The balloon tubes mentioned are sold by surgical supply houses and are known as "Patton" or "Sangstaken" tubes for esophageal hemorrhage control.

16. Phemister, D. B., and Humphreys, E. M.: Gastro-Esophageal Resection and Total Gastrectomy in the Treatment of Bleeding Varicose Veins in Banti's Syndrome, Ann. Surg. **126**:397, 1947. Lendrum, F. C.: Personal communication to the authors. Schafer, P. W., and Kittle, C. F.: Partial Esophagogastrectomy in the Treatment of Esophagogastric Varices, Arch. Surg. **61**:235 (Aug.) 1950. Capps.[6]

EFFECT OF PORTACAVAL VENOUS SHUNT ON SULFOBROMOPHTHALEIN (BROMSULPHALEIN®) RETENTION

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AND
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DETROIT

THE CONSTRUCTION of large shunts between the portal and caval systems of veins constitutes a logical method of treating patients with bleeding esophageal varices associated with portal hypertension. Both splenorenal and portacaval anastomoses have been used with success for this condition, some surgeons preferring the one and some the other type of operation. However, the procedure, which is most physiological as far as liver function is concerned, remains open to some question.

Whipple and his co-workers [1] have shown that dogs with complete shunts of the portal blood away from the liver (Eck fistula) fail to regenerate protein and hemoglobin in a normal manner, and Mann and others [2] demonstrated years ago that the livers of Eck fistula animals fail to regenerate after partial hepatectomy. On the basis of this evidence, as well as on theoretical grounds, it would seem wise to recommend the construction of partial rather than complete portacaval shunts in patients who are operated on for portal hypertension. Further evidence in support of this view is presented in the experiments reported in this paper.

METHOD

Medium-sized mongrel dogs were used as experimental animals. Side to side and end to side portacaval shunts were constructed according to a method described in detail elsewhere.[3] Briefly, the vena cava was partly occluded by a specially designed clamp, the portal vein and its tributaries temporarily occluded with braided silk slip knot ties or loops and the anastomosis constructed by using continuous everting mattress sutures of fine silk.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

From the Department of Surgery, Wayne University College of Medicine and the Detroit Receiving Hospital.

1. Whipple, G. H.; Robscheit-Robbins, F. S., and Hawkins, W. B.: Eck Fistula Liver Subnormal in Producing Hemoglobin and Plasma Proteins on Diets Rich in Liver and Iron, J. Exper. Med. **81**:171-191 (Feb.) 1945.

2. Mann, F. C.; Fishback, F. C.; Gay, J. G., and Green, F. G.: Experimental Pathology of the Liver, Arch. Path. **12**:787-793 (Nov.) 1931.

3. Large, A.; Johnston, C. G., and Preshaw, D. E.: The Portacaval Venous Shunt, to be published.

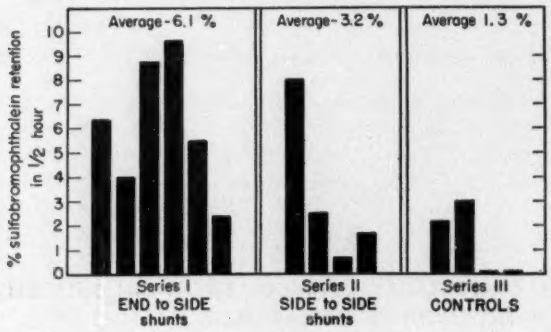

Fig. 1.—Each block represents the sulfobromophthalein retention for one experimental animal prior to carbon tetrachloride administration.

TABLE 1.—*Percentage of Sulfobromophthalein Retention in Half an Hour*

CCl_4 per Kilogram, Cc.	Series 1 Complete Portacaval Shunts						Series 2 Partial Portacaval Shunts				Series 3 Normal Controls			
	Dog 2	Dog 21	Dog 25	Dog 33	Dog 37	Dog 44	Dog 22	Dog 38	Dog 43	Dog 45	Dog 51	Dog 52	Dog 53	Dog 54
0	6.3	4.0	8.8	9.6	5.5	2.3	8.0	2.5	0.7	1.6	2.2	3.0	0	0
0.25	49.8	44.3	41.0	45.0	39.0	22.3	15.0	2.0†	26.0	3.6	....	....	....	....
0.5	49.8	28.2	34.8*	21.0	38.0*	61.0	14.0	....	0	2.5	3.0	4.0	4.0	0
1	49.8	50.1	....	22.0	....	67.0*	23.0	....	6.2	17.0	1.3	0	0	0
2	48.2*	50.2	....	60.0	....	....	28.0	....	12.0*	17.0	4.7	1.6	5.3	0
4	....	47.0*	....	74.5*	....	....	27.0	....	....	15.0†	13.8	17.2*	2.3*	0
6	....	....	....	....	....	....	16.5	....	....	....	4.0	....	....	1.5
8	....	....	....	....	....	....	23.5	....	....	....	8.7	....	....	0
12	....	....	....	....	....	....	22.6†	....	....	....	14.3†	....	....	16.0†

* Died. † Killed.

TABLE 2.—*Average Percentage of Sulfobromophthalein Retention in Half an Hour*

CCl_4 per Kilogram, Cc.	Series 1 Complete Shunts, %	Series 2 Partial Shunts, %	Series 3 Controls, %
0	6	3	1
0.25	40	10	..
0.5	39	5	3
1	47	15	1
2	53	19	3
4	61	21	8
6	..	17	3
8	..	23.5	5
12	..	22.6	15

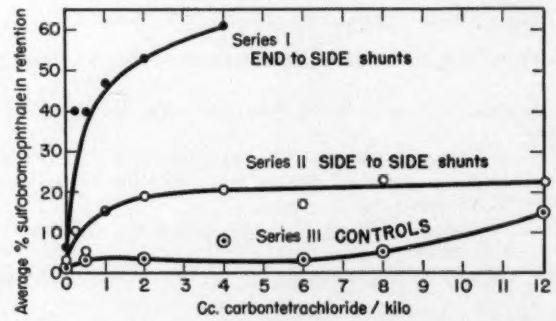

Fig. 2.—Average percentage of sulfobromophthalein retention for each group of animals plotted against dose of carbon tetrachloride. All six animals with complete shunts (series 1) were dead by the time 4 cc. of carbon tetrachloride per kilogram had been given.

Three groups of dogs were prepared. Series 1 consisted of six animals with end to side anastomoses (Eck fistula); series 2 of 4 dogs with side to side anastomoses, the poral vein being left open between the shunt and the liver, and series 3 comprised 4 normal controls.

At least one month, usually longer, after operation, when the animals appeared to be in good health, determinations of sulfobromophthalein (bromsulphalein®) retention were done. In previous experiments [4] we had used a comparator block with known concentrations of dye in each tube to determine the sulfobromophthalein content of serum. The results of this method, however, were unsatisfactory. Therefore in the present experiments, sulfobromophthalein determinations were done after the more accurate method of Drill.[5] Five milligrams of sulfobromophthalein per kilogram of body weight were injected intravenously during the fasting state and specimens of blood collected a half hour later. Serum was obtained as rapidly as possible, alkalinized and its sulfobromophthalein content determined on the Evelyn filter photometer. This method, as well as being accurate, eliminates errors due to extraneous discoloration of the serum.

Next, carbon tetrachloride was given to test the functional reserve of the liver. Lamson and McLean [6] have shown that when this drug is administered to dogs, a definite depression of liver function may be expected. This effect is maximal after 48 hours and then rapidly disappears. Doses of the drug previously administered do not appear to have a cumulative effect, although cirrhosis may be produced if alcohol and carbon tetrachloride are administered together over long periods.

Carbon tetrachloride in vegetable oil was administered by stomach tube in equal doses per kilogram of body weight to each dog in the experiment and determinations of sulfobromophthalein retention done 48 hours later. Each week the dose of carbon tetrachloride was increased and the experiment repeated. At the conclusion of the experiment all the animals with shunts were killed and the patency of the anastomoses verified.

RESULTS

The percentage of sulfobromophthalein retention for each animal prior to the administration of carbon tetrachloride is shown in figure 1. The animals with complete diversion of the portal flow (series 1, Eck fistulas) averaged 6.1 per cent retention, those with partial shunts (series 2, side to side anastomoses) averaged 3.2 per cent and the controls (series 3) averaged 1.3 per cent.

Table 1 gives the response of each animal to increasing doses of carbon tetrachloride. The sulfobromophthalein determinations, as already mentioned, were made 48 hours after each dose of carbon tetrachloride was given. Table 2 shows the average retention of each group at increasing doses of carbon tetrachloride, and these figures are represented graphically in figure 2.

COMMENT

The differences in sulfobromophthalein retention between normal animals and those with portacaval shunts prior to carbon tetrachloride poisoning are not great but are probably constant enough to be of some significance. These differences may be due to the decrease in blood flow through the liver in the shunted animals, to an actual decrease in liver function, or to both of these factors.

On the other hand, table 1 shows that the animals with complete shunts showed sulfobromophthalein retention so rapidly and died so much more quickly as a result

4. Large, A., and Preshaw, D. E.: The Eck Fistula: An Experimental and Clinical Study, J. internat. chir. **10**:139-145 (May-June) 1950.

5. Drill, V.: Personal communication to the authors.

6. Lamson, P. D., and McLean, A. J.: The Toxicity of Carbon Tetrachloride: In Relation to Liver Function as Tested by Phenoltetrachlorphthalein, J. Pharmacol. & Exper. Therap. **21**:237-246 (May) 1923.

of carbon tetrachloride poisoning than did either the partially shunted animals or the controls that a marked decrease in hepatic reserve in these Eck fistula animals must be accepted as proved. Figure 2 further shows that the animals with partial shunts reacted to carbon tetrachloride poisoning in a manner similar to that of the controls and not at all like that of the animals with complete shunts.

The inference is obvious. Since the Eck fistula liver does not tolerate damage as well as does the normal liver or the liver with its portal flow partly diverted, it is reasonable to assume that the already damaged human cirrhotic liver might be further embarrased by complete diversion of the portal blood to the vena cava. It is therefore suggested that shunt operations for portal hypertension in patients should, if possible, be designed to relieve the hypertension without completely interrupting portal blood flow to the liver. Side to side portacaval anastomosis or splenectomy with end to side splenorenal anastomosis would satisfy these requirements.

SUMMARY

Experimental evidence is presented to show the effect of partial and complete diversion of the portal blood flow on the ability of the liver to withstand carbon tetrachloride poisoning, using sulfobromophthalein (bromsulphalein®) retention as an index of liver function.

Animals with complete shunts tolerate carbon tetrachloride poisoning poorly as compared to animals with partial shunts and to normal controls. It is therefore suggested that operations for the relief of portal hypertension in patients be designed to relieve the hypertension without completely shunting the portal blood flow away from the liver.

DISCUSSION

Dr. Willis D. Gatch, Indianapolis: If you express portal pressures not in units of water but in units of mercury, they do not seem to be so great. We have demonstrated that the pressure in any vein within the abdomen must equal the intra-abdominal pressure. If it does not equal this no blood can flow through it. This pressure, of course, comes from the heart. In the portal vein the pressure must exceed the intra-abdominal pressure enough to force blood through the liver. Mann and others have shown that this amount is about 5 to 6 mg. of mercury. Without this head of pressure in the portal vein no blood can flow from it through the liver. The pressure at a lateral anastomosis between the portal vein and the inferior vena cava has been measured by canalization and found equal to the intra-abdominal pressure. Therefore it is hard to see how, under these conditions, blood can ever flow from the portal vein through the liver.

Dr. Rudolf J. Noer, Detroit: Portal cirrhosis with its complications presents a problem for which we still lack adequate solution. Bleeding esophageal varices, with their hazard of rapid exsanguination, have stimulated surgeons to devise various operative procedures aimed at the prevention of recurrent hemorrhage. Among these operations, attempts to relieve portal hypertension by shunt operations appear to be a logical approach to the problem. The authors' application of the Pott's clamp principle to the technic of partial diversion of portal blood flow has been an interesting development. This technic has greatly simplified the operation, and shunts now have been carried out by this method in 18 patients.

It has been my privilege to observe most of these persons before and after operation, and it has been most encouraging to see the relief many have experienced from repeated hemorrhage. It is my impression that ascites and the other complications of cirrhosis have received no benefit whatever from this operation. However, if some form of portal blood diversion can

free these patients from the hazards of repeated esophageal bleeding the procedure still will have been worth while. Ten of 12 patients operated on for this symptom alone have remained free of further bleeding for periods up to two and a half years.

The experimental work presented by Dr. Large this afternoon represents many months of careful observation aimed at determining the best type of shunt in terms of the ultimate effect on the organism. The differences between his series are striking. The results would appear to indicate definitely that the hazard of complete diversion of the portal blood flow is considerable. If portacaval shunts are to be done, it appears wise to divert only a portion of the portal blood flow in an attempt to conserve what little hepatic function remains for these unfortunate patients suffering from portal cirrhosis.

EFFECT OF OCCLUSION OF THE ARTERIAL BLOOD SUPPLY TO THE NORMAL LIVER

An Experimental Study

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AND
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FROM the beginning of his medical training the surgeon is taught to respect the hepatic artery. Technics of operations performed in the region through which this vessel courses have as their common objective the avoidance of the normal or aberrant artery and its hepatic branches, so great is the fear of the hepatic artery and so certain and so rapid the onset of liver necrosis and coma followed by death if it or one of its branches is ligated. Fortunately, because of the surgeon's training, opportunities for study of the events following ligation which lead to death are rare in the case of man. In regard to dogs, it has been held that lack of arterial blood is but the beginning of liver damage and that an anaerobic bacillus, found by Wolbach and Saiki [1] to be present in the liver of many normal dogs and proved by many to be capable of causing rapid autolysis of liver tissue, implanted into the peritoneal cavity or otherwise deprived of circulation, plays an important part in the dissolution of liver.

Lately, Markowitz, Rappaport and Scott [2] have reported a study in which the hepatic artery was ligated in dogs and in which most dogs that received penicillin survived. They concluded that deprivation of arterial blood to the liver was disastrous because it provided an opportunity for proliferation of an anaerobe such as that described by Wolbach and Saiki. They attributed survival of their dogs to prevention of such bacterial growth by the antibiotic action of penicillin. Their work, although it is an important contribution, leaves questions still to be answered, questions such as whether ligation of the hepatic artery totally deprives the liver of arterial blood, whether ligation only temporarily deprives the liver or diminishes its supply of arterial blood and whether recovery of the liver can occur in the absence of arterial blood. Viewed from points suggested by these questions,

From the Division of Experimental Medicine, Mayo Foundation.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

1. Wolbach, S. B., and Saiki, T.: A New Anaerobic Spore-Bearing Bacterium Commonly Present in the Livers of Healthy Dogs, and Believed to be Responsible for Many Changes Attributed to Aseptic Autolysis of Liver Tissue, J. M. Res. **21**:267-278, 1909.

2. Markowitz, J.; Rappaport, A., and Scott, A. C.: The Function of the Hepatic Artery in the Dog, Am. J. Digest. Dis. **16**:344-348, 1949.

penicillin and possibly other antibiotics may be agents to be used to study what hitherto was obscure because of the masking effect of bacterial invasion.

Our study was prompted by the realization that penicillin might permit us to learn whether in dogs ligation of the hepatic artery stopped all inflow of arterial blood, either temporarily or permanently, and to observe whether restoration of arterial supply occurred in dogs which might recover after penicillin therapy. It was not within the scope of the study to investigate the antibiotic action of penicillin in the liver after ligation of the hepatic artery or to ascertain the relative importance of arterial blood supply to the various cellular components of the liver.

METHODS AND MATERIALS

Healthy adult, mongrel dogs were used in this study. All operations were performed with the animal under ether anesthesia and with aseptic technic. Dogs which received penicillin were given 100,000 units of penicillin chloride intraperitoneally at the time of operation and 100,000 units of procaine penicillin G in oil intramuscularly daily for the first four or five days after operation. The regular kennel diet was offered to all dogs. If they refused this, they were offered milk and dextrose. Dogs which would not eat were given 5 per cent dextrose solution intravenously.

A simple roentgenographic technic was used to demonstrate the arterial supply of the liver. The technic was used equally well for the dogs which died and the dogs killed under ether anesthesia by rapid hemorrhage from a carotid artery. First, the aorta was ligated immediately above the origin of the renal arteries. A cannula was then placed in the thoracic aorta, slipped downward to the lower part of the thorax and held secure by ligatures which compressed the aorta tightly about the cannula. A warm mixture of powdered barium sulfate suspended in gelatin solution was then injected through the cannula. The arteries of the lower part of the thorax and upper part of the abdomen filled rapidly with the injection mass. After a period of refrigeration, during which the gelatin became firm, the liver was removed and a roentgenogram of it was taken. While the liver was being removed the number and diameter of arteries in the diaphragmatic ligaments and other structures could be observed easily because of their white opacity. Sections of the liver were taken for histologic study after the roentgenogram had been made.

EXPERIMENTS

Several critical experiments were performed on healthy dogs to determine whether arterial blood could still reach the liver after ligation of the hepatic artery. First, it was seen from roentgenograms of the liver that the intrahepatic arterial system was demonstrated equally well whether the injection was performed directly into the hepatic artery or into the lower thoracic and upper abdominal aorta, the hepatic artery in both cases being unobstructed.

In another experiment the main hepatic artery was ligated and, distal to this point, the right gastric, gastroduodenal and all other branches of the artery except those going to the liver were ligated. The main hepatic artery was ligated in another dog, and all the visible branches of the artery leading to the liver were ligated. The livers of both dogs showed good filling of the intrahepatic arterial system. In both dogs it could be demonstrated that the branches of the hepatic trunk had been ligated too close to their point of origin and that in both dogs the hepatic branches had been filled by way of small arteries in the gastrohepatic ligament which linked hepatic branches to arteries in the pyloric and pancreaticoduodenal regions.

Additional critical experiments demonstrated that arterial blood could be prevented from entering the liver at its hilus only when the hepatic branches were ligated close to the hepatic hilus or when all tissue in the gastrohepatic ligament

and omentum other than the common duct and portal vein was secured by clamp or ligature.

Surgical ligation of the branches of the hepatic artery entering the liver was performed in 16 dogs by the technic which had been demonstrated in the critical experiments to be reliable and effective. All tissue of the gastrohepatic ligament and omentum except bile ducts and portal vein was surrounded by many ligatures and tied securely. Cholecystectomy was accomplished at the same time. Ten of these dogs were treated with penicillin, and six were untreated.

Untreated Dogs.—All six dogs which did not receive penicillin were found to be in shock or coma a short time after recovery from anesthesia. Two dogs died within six to eight hours after operation, three dogs lived for 12 to 18 hours and one dog lived for almost 24 hours. Necropsy showed the presence in the abdominal and pleural cavities of bloody fluid having a foul odor. When the dog could be examined within an hour after death, the liver was mottled, covered by a thin fibrinous film and rather soft. Gas bubbles within the liver were not noted unless the interval between death and necropsy was several hours. Histologic sections showed massive necrosis of hepatic parenchyma and hemorrhage.

Treated Dogs.—All 10 dogs which received penicillin for the first three or four days after operation survived at least five days; all, however, appeared more or less ill. Jaundice developed in five dogs, which gradually became moribund. One died five days and another 19 days after operation; one was killed on the seventh, one on the ninth and the fifth on the fourteenth day. The jaundice appeared to be of intrahepatic origin. The liver of the dog which lived 19 days was hard to recognize. It was dark and extremely soft, and several lobes had disappeared except for a few fibrous elements. A roentgenogram of the liver after injection of the aorta showed a few small arteries in the hilar region. Lower, although conspicuous, degrees of autolysis of liver were seen in the four dogs which lived from five to 14 days. A few small arteries in the hilar region were demonstrated in the dogs living five and nine days. No arteries could be seen in the liver of the dog killed on the seventh day, and no arteries were seen in the right lobe of the liver of the dog killed on the fourteenth day.

In five dogs jaundice did not develop. Three of these were killed after they seemed to have recovered from the effects of operation, one at three weeks, one at five weeks and another at seven weeks. The liver of the dog killed at five weeks appeared normal except for a moth-eaten series of depressions along the edge of the left lobe. Injection of the liver showed good filling of the arterial system in all lobes except the left, where only a few vessels could be seen at the hilus. The dog killed at three weeks showed similar changes in the edge of the right lobe. The liver of the dog killed at seven weeks appeared normal, although all surfaces were adherent to adjacent organs. The arterial system of the liver of this dog filled well, although the pattern of the vessels in the right lobe was not normal. Many of the arteries of the right lobe seemed to arise not from the hilus but from the surface where the liver had been adherent to the pancreas.

Two dogs have been left for longer periods of observation. Both are well three months after operation.

When the liver was removed from the dogs treated with penicillin, its attachments were inspected carefully. In each of the three dogs in which jaundice did not

develop and which were killed, many small, though much larger than normal, vessels containing barium were seen in the diaphragmatic-hepatic ligaments and on the surface of the vena cava just below the diaphragm. A few similar vessels were seen on the surface of the common duct. Whenever the liver was adherent to the diaphragm, abdominal wall or other viscera, a fibrillary network of extremely small barium-filled vessels ran between the liver and the adherent organ.

COMMENT

Our experiments appear to confirm the report by Markowitz, Rappaport and Scott that penicillin prevents early death of dogs after an effective ligation of the hepatic artery. The beneficial effect of penicillin may well be inhibition of growth of an anaerobic bacterium. Such a bacterium would presumably find fertile soil for rapid growth in dead or severely damaged hepatic lobules under the relatively low blood oxygen tension resulting from lack of arterial blood supply. The rapid development of severe shock, and early death, may be caused mainly by greatly increased liberation of toxic substances released by bacterial action on hepatic tissue.

Our study did not show, on the other hand, that penicillin would protect the liver from all effects of deprivation of arterial blood. All the treated dogs were sick for a time after operation, including the time they were receiving penicillin. Their behavior and the development of jaundice by the sickest dogs pointed to impaired hepatic function or complete hepatic failure. There was no evidence that penicillin affected the development of signs of hepatic failure, nor any evidence from examination of the liver of the dog which died on the fifth day, the last day of penicillin administration, that simple autolysis had been inhibited.

Recovery of the treated dogs appeared to be related to development of an adequate number of collateral vessels supplying the intrahepatic arterial system. Among the five dogs which died or were moribund, no significant amount of injection mass could be seen to reach the liver after arterial injection in the case of four dogs and no material entered a major lobe of the other dog. Arterial injection of three of the five dogs which recovered and were killed demonstrated good filling of the intrahepatic arterial system, except for a small necrotic region at the edge of one lobe of two dogs. Instead of entering the liver through the hepatic artery, the injection mass reached the intrahepatic arteries mainly by way of vessels coming from the diaphragm which are present normally, but small and inconspicuous, and which had enlarged to many times their normal size. Presumably in the two dogs which recovered and are living three months after operation collateral hepatic arterial supply has also developed.

SUMMARY

Arterial blood may be prevented from reaching the liver of the dog if the branches of the hepatic artery are ligated close to the hilus of the liver. Ligation of the hepatic artery in this fashion resulted in death of control dogs within 24 hours. Ligation of the artery in dogs which were treated with penicillin for four or five days after operation was followed by survival of all dogs for at least five days. Some of the penicillin-treated dogs became moribund and died or were killed between five and 19 days after operation. All had severe degrees of hepatic necrosis. It was demonstrated that arterial supply of the liver of these dogs was absent or

limited and that it was entirely absent in regions that became necrotic. The other treated dogs recovered. Some have been killed at intervals of three to seven weeks after operation, and their livers have been examined. Except for a small region of hepatic necrosis in each of two dogs, the livers of these dogs were demonstrated to have a good arterial supply. Presumably the arterial supply was reestablished by way of collateral vessels in the diaphragmatic ligaments, on the surface of the common duct and of the vena cava below the diaphragm and possibly from neighboring organs by way of adhesions. Two dogs are well three months after operation. Presumably a collateral arterial supply to their livers also has developed.

DISCUSSION

DR. J. K. BERMAN, Indianapolis: I have been very much interested in this paper by Dr. Grindlay and his associates, because for the past three years we have been working along similar lines. I shall start my brief discussion by giving you our conclusions, and then, if time permits, I should like to give you a résumé of our experimental work.

We have been able to tie the hepatic artery and the splenic artery in the dog with a sustained fall in portal pressure. Recently we have had an answer to our prayer, from the Department of Gastroenterology of the Indianapolis General Hospital, and have tied the hepatic artery and the splenic artery in a man with advanced cirrhosis of the liver who has been in and out of our hospital for over two years, with some 20 paracenteses, averaging about 17,500 cc. per month. In the first 48 hours after this procedure some ascites developed; however, after that time there has been no reaccumulation of fluid. He received 500 cc. of blood before and 500 cc. during the operative procedure. Shortly thereafter, and as of the day before yesterday, his serum albumin was 3.5 Gm. without any further transfusion. His urinary sodium rose from 27 to 90 milliequivalents in each 24 hours.

If time permits, I should like to discuss some of the reasons for this. The conclusions and the entire work will be the subject of a paper by my colleagues and me in the near future. I do not know whether you can see this or not, so I shall read it quickly:

[Slide] I. Survival after ligation of hepatic artery

- A. Without preparation with penicillin and streptomycin.
  - 1. Ligation close to liver causes death due to liver necrosis and gangrene of gallbladder with bile peritonitis in many instances.
- B. Preparation with penicillin and streptomycin.
  - 1. Ligation close to liver causes death due to liver necrosis.
  - 2. Ligation at source results in survival if dogs are cared for properly.

II. Collateral circulation after ligation of hepatic artery at source

- A. Injection of diodrast® through catheter introduced into right common carotid down to celiac axis.
  - 1. Prodigious collateral circulation demonstrated.
- B. Injection directly into aorta above the inferior mesenteric artery with temporary ligature below the site of injection.
  - 1. Extensive collateral circulation demonstrated.
- C. Injection of dicetylphosphate in olive oil into the hepatic artery before ligation causes death within a few hours due to hepatic insufficiency. One month after ligation injection of the same substance into a collateral does not cause death of animal.

III. Effect of ligation of hepatic artery at celiac axis on portal venous pressure

- 1. Fall of 10 to 20 mm. of water results.
- 2. Systemic arterial pressure remains constant as shown by simultaneous recordings in femoral artery.

IV. Effects of ligations of hepatic and splenic arteries on portal venous pressure

A. Ligation of splenic artery after the hepatic artery has been tied causes an additional drop in portal venous pressure of 40 to 50 mm. of water.

1. Systemic arterial pressure remains constant.

B. Ligation of splenic artery first causes a slight fall in portal venous pressure equal to 5 to 10 mm. of water. After hepatic artery ligation there is an additional fall of 40 to 60 mm. of water.

C. Ligation of the hepatic artery and then the splenic artery one month later causes an additional fall in portal pressure. If the splenic artery is tied first and then the hepatic artery 30 days later, there is a precipitous fall in portal pressure.

D. Ligation of the celiac axis produced a fall in portal pressure of 40 to 60 mm. of water.

1. Apparently the occlusion of the left gastric artery does not affect portal venous pressure because when it is tied alone no change occurs.

E. Splenectomy caused a slight added fall in portal pressure for about 20 minutes and then a rise slightly above that which occurs without splenectomy.

V. Effects of ligation of hepatic and splenic artery after attempts to produce portal hypertension

A. Injection of dicetylphosphate around portal vein causes enormous fibroplasia. After 30 to 60 days collaterals appear in gastrohepatic ligament; portal venous pressures are only slightly higher.

1. Ligation of hepatic and splenic arteries produced a fall in portal venous pressures of 30 to 40 mm. of water.

B. Injection of dicetylphosphate around the inferior vena cava above the diaphragm produced a slight rise in portal venous pressure after 30 days.

1. Effects of hepatic and splenic artery ligation are the same as in A.

C. Partial ligation of the interior vena cava above the diaphragm with polythene film produced a greater rise in portal venous pressure than in B.

1. Results of hepatic and splenic artery ligations were the same as in A and B.

2. Side to side portacaval shunt prior to ligation of the hepatic and the splenic artery did not change the results. Ligation of the portal vein distal to the portacaval shunt caused a transient rise in portal pressure followed by a fall greater than in A, B or C.

[Slide] This shows a portal vein on the left at the site of the injection of dicetylphosphate in olive oil and on the right the same vein closer to the liver. Note the enormous amount of fibroplasia.

[Slide] This is a graph, and I will admit that making graphs with a cannula or a large 18 gage needle in the portal vein of a dog is difficult; but with the addition of heparin or the use of citrate solution the cannula may be kept open.

On the left is the normal pressure. The first arrow points to the ligature on the splenic artery and then the ligature on the hepatic artery. The start was 115 mm. of water. There was a fall to 96 mm. of water and then a fall to 6 mm. of water. At no. 3 the spleen was removed. There was a slight fall. Twenty minutes later, however, the portal pressure came back up to 12 mm. of water.

In conclusion, and without discussion as to the causes or the physiological considerations for the effectiveness of the procedure, I wish to suggest for your consideration that the treatment of the bad effects of portal hypertension, namely, bleeding esophageal and other varices and ascites, may be controlled by the simultaneous ligation of the hepatic and splenic arteries.

OPEN VERSUS CLOSED METHOD OF COLON ANASTOMOSIS

C. FREDERICK KITTLE, M.D.
THOMAS G. ORR Jr., M.D.
AND
THOMAS G. ORR, M.D.
KANSAS CITY, KAN.

THE OPERATION of choice for resection of the bowel is one that can be done with the greatest ease and which will produce as good or better results than any other technique.

For more than 100 years surgeons have been interested in bowel anastomosis, and during this time many methods have been tried, with more or less success. Parker and Kerr [1] stated that prior to 1908 no less than 200 methods of intestinal suture had been described. The first intestinal anastomoses were made by the open method. The morbidity and mortality were so great with this method that surgeons were stimulated to perfect other techniques to avoid the much feared peritonitis resulting from peritoneal contamination at the time of operation and later from leakage at the suture line. During the last 50 years the exteriorizing, obstructive resection, aseptic (closed) and open operations have had their adherents. Some of the opinions of leading surgeons expressed during the last 20 years are here briefly discussed.

The exteriorizing operations (Mikulicz type) were for many years the techniques of choice of many surgeons. The outstanding modification of these techniques was the obstructive resection operation of Rankin,[2] which reduced to some extent the danger of colon resection. Cheever [3] (1931) considered the Mikulicz operation inferior to primary resection and anastomosis. He advised diversion of the fecal stream by cecostomy or, better, by a permanent type of colostomy, to be followed by resection and open anastomosis. Ochsner and DeBakey [4] (1939) concluded that "even though preoperative preparation can be satisfactorily performed in left-sided lesions, a primary resection of the colon with

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Fellow, American Cancer Society (Dr. Kittle).

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

1. Parker, E. M., and Kerr, H. H.: Intestinal Anastomosis Without Open Incisions by Means of Basting Stitches, Bull. Johns Hopkins Hosp. **19**:132 (May) 1908.

2. Rankin, F. W.: Modern Management of Cancer of the Lower Gastro-Intestinal Tract, Surg., Gynec. & Obst. **74**:905 (May) 1942.

3. Cheever, D.: The Choice of Operation in Carcinoma of the Colon, Ann. Surg. **94**:705 (Oct.) 1931.

4. Ochsner, A., and DeBakey, M.: Operability, Morbidity and Mortality Factors in Carcinoma of the Colon, Am. J. Surg. **46**:103 (Oct.) 1939.

immediate anastomosis should never be done." Garlock and Klein [5] (1949) warned that the "operation of obstructive resection is still an excellent one and should not be discarded in the wave of enthusiasm for the operation of resection and primary anastomosis." Rankin [2] (1942), who has long been an advocate of obstructive resection of the colon, was of the opinion that "in the modern management of colon cases and with the new chemotherapeutic agents available to sterilize the bowel, one may be quite justified in doing an open anastomosis if that is deemed preferable." Stone and McLanahan [6] (1942) commented on the above statement of Rankin as follows: "While it is undoubtedly true, it carries with it an implication of a temptation to let up a little on standards of technic, to which temptation the conscientious surgeon will not allow himself to succumb." Stone and McLanahan advised resection and immediate anastomosis, utilizing the aspects of the aseptic technique, but stated that they had no intention of presenting the aseptic method as the only proper procedure. Whipple [7] (1943) advocated decompression of the proximal bowel with a Miller-Abbott tube and resection and anastomosis by the open method, which he believed to be as safe an operation as the so-called aseptic methods and to result in more accurate suture technique with a greater certainty of an adequate stoma.

Jones [8] (1943) had the following to say about colon resection: "Whether it is done by the closed or open method, by the one-stage or two-stage method, or by any other technique, makes little difference provided the surgeon can show that his results from the standpoint of mortality and morbidity are equal to those of other techniques." Ochsner [9] (1943) in an editorial expressed his opinion that "unquestionably, the use of aseptic methods of anastomosis has done much to improve the results and decrease the morbidity. An aseptic anastomosis is technically more difficult to perform than open anastomosis and will be used more frequently by the more experienced surgeons than by occasional operators." Fallis [10] (1943) used the closed anastomosis with a modified Furniss clamp but suggested that "an open anastomosis is just as readily carried out and perhaps permits more accurate suturing." Coller and Vaughan [11] (1945), in discussing closed and open anastomoses, stated that "the aseptic method has become increasingly more popular with our

5. Garlock, J. H., and Klein, S. H.: Carcinoma of the Colon and Rectum: A 10 Year Study, Arch. Surg. **59**:1289 (Dec.) 1949.

6. Stone, H. B., and McLanahan, S.: Resection and Immediate Aseptic Anastomosis for Carcinoma of the Colon, J. A. M. A. **120**:1362 (Dec. 26) 1942.

7. Whipple, A. O.: Symposium on Surgical Management of Malignancy of the Colon: Surgery of the Terminal Ileum, Cecum and Right Colon, Surgery **14**:321 (Sept.) 1943.

8. Jones, T. E.: Symposium Surgical Management of Malignancy of the Colon, Consideration of Elective Surgical Procedures in Various Segments of the Colon, Surgery **14**:342 (Sept.) 1943.

9. Ochsner, A.: Cancer of the Colon, editorial, Surgery **14**:433 (Sept.) 1943.

10. Fallis, L. S.: Symposium on Surgical Management of Malignancy of the Colon, Anterior Resection of the Rectosigmoid and Upper Rectum with Re-Establishment of Continuity, Surgery **14**:397 (Sept.) 1943.

11. Coller, F. A., and Vaughan, H. H.: Treatment of Carcinoma of the Colon, Ann. Surg. **121**:395 (April) 1945.

surgeons. It is felt that both methods are satisfactory." Wangensteen's [12] (1945) choice was a closed method of anastomosis with a clamp which he designed. In resections of the rectal ampulla, he found that primary healing after the closed operation occurred in a minority of cases. This morbidity was attributed to disturbance of blood supply to the rectum and not to the closed method of anastomosis. Preliminary or complemental colostomy was not advised by Wangensteen. Waugh and Custer [13] (1945) believed that the use of sulfonamides and aseptic anastomosis were factors in the reduction of the mortality rate. These authors decided that "proximal colostomy or prophylactic decompression with a rectal tube is indicated when lesions of the lower part of the sigmoid or below are removed." They did not recommend colostomy for resections above the sigmoid. The one stage resection and open anastomosis without complemental colostomy was favored by Meyer and his associates [14] (1945). Lahey [15] (1946) has been a strong advocate of the Mikulicz type of operation even for resection of the right side of the colon. In a discussion of the merits of this operation he remarked that "we do not wish to argue with anyone against primary anastomosis. No one method, either the Mikulicz or primary anastomosis, is the best for everyone and for every case." Lahey supported his good opinion of the Mikulicz operation by reporting a mortality rate of 2.7 per cent. McNealy and Lands [16] (1947) disapproved of the closed or aseptic method of anastomosis, pointing out that suturing is difficult about clamps and the clamps are difficult to remove after anastomosis is completed. They used two rows of interrupted sutures for the open anastomosis. They did not use complemental colostomy. For many years Allen [17] used some form of closed anastomosis but in 1947 recommended open anastomosis, using an inner row of surgical gut and an outer row of cotton sutures. MacFee [18] (1947) preferred the one stage resection and anastomosis but did not state his preference for either the closed or the open technique. He was specific in his opinion that "one of the greatest single measures of safety in resection and suture at the rectosigmoid level is a transverse colostomy performed several days in advance and completely diverting the feces." For resections of the right side of the colon Mayo [19] (1947) employed a one stage right

12. Wangensteen, O. H.: Primary Resection (Closed Anastomosis) of Rectal Ampulla for Malignancy with Preservation of Sphincteric Function Together with Further Account of Primary Resection of Colon and Rectosigmoid and Note on Excision of Hepatic Metastases, Surg., Gynec. & Obst. **81**:1 (July) 1945.

13. Waugh, J. M., and Custer, M. D., Jr.: Segmental Resection of Lesions Occurring in the Left Half of the Colon with Primary End-to-End Aseptic Anastomosis: Report Based on 50 Cases, Surg., Gynec. & Obst. **81**:593 (Dec.) 1945.

14. Meyer, K. A.; Sheridan, A., and Kozoll, D. D.: One Stage "Open" Resection of Lesions of the Left Colon Without Complementary Colostomy, Surg., Gynec. & Obst. **81**:507 (Nov.) 1945.

15. Lahey, F. H.: A Discussion of the Modified Mikulicz Operation for Carcinoma of the Colon and Its Technic, S. Clin. North America **26**:610 (June) 1946.

16. McNealy, R. W., and Lands, V. G.: Primary Anastomosis in Treatment of Carcinoma of the Colon, Surgery **21**:283 (March) 1947.

17. Allen, A. W.: Carcinoma of the Large Intestine, S. Clin. North America **27**:1018 (Oct.) 1947.

18. MacFee, W. F.: The Management of Carcinoma in the Several Parts of the Colon, Ann. Surg. **126**:125 (Aug.) 1947.

19. Mayo, C. W.: Carcinoma of the Right (Proximal) Portion of the Colon, S. Clin. North America **27**:875 (Aug.) 1947.

colectomy with an end to end open type of ileotransversecolostomy. He did not think it necessary to use the Miller-Abbott tube except when there is obstruction. A mortality rate of 3 per cent lends support to Mayo's opinion. Dixon [20] (1948) reported his use of the open operation for anterior resections of lesions in the

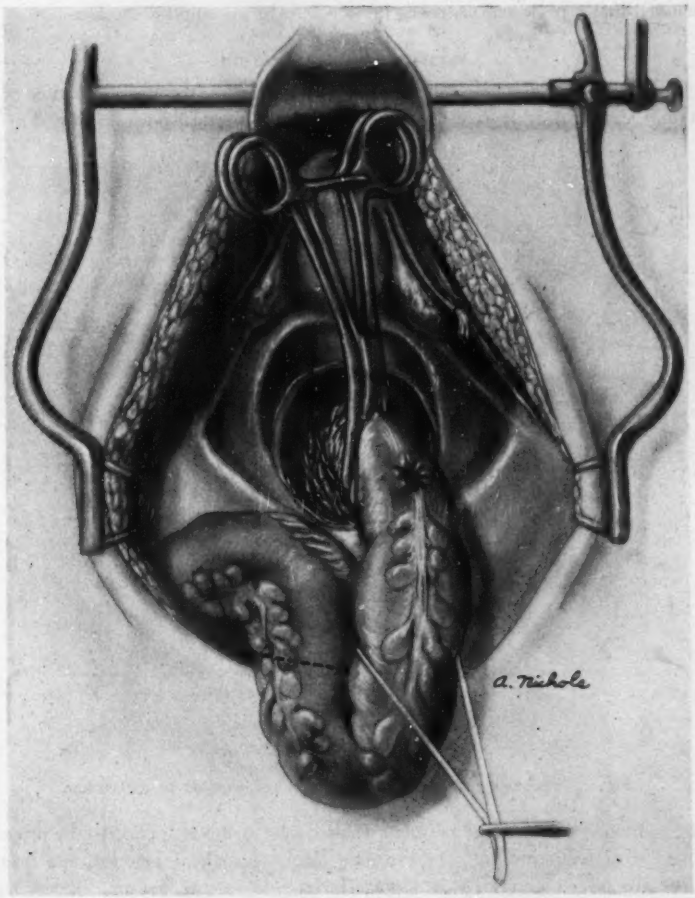

Fig. 1.—Clamps placed vertically on the upper part of the rectum for resection of the upper part of the rectum and the sigmoid.

rectosigmoid. At the close of the operation a complemental transverse colostomy was made. His mortality rate in seven years was reduced to 2.6 per cent. In the

20. Dixon, C. F.: Anterior Resection for Malignant Lesions of the Upper Part of the Rectum and Lower Part of the Sigmoid, Ann. Surg. **128**:425 (Sept.) 1948.

year 1949 Maes and Essrig [21] expressed their preference for the open operation. Gunkler and Pearse [22] (1949) have used both open and closed anastomosis without demonstrable difference in mortality and morbidity between the two methods. In reviewing their cases Rosemond and his co-workers [23] (1949) found a higher morbidity with the closed method than with the open method of anastomosis. They concluded that a proximal vent was unnecessary in uncomplicated cases.

TECHNIQUE OF OPERATION

For resections of the lower part of the sigmoid or the upper portion of the rectum, Ockerblad or Payr clamps are applied in a vertical position (fig. 1). The

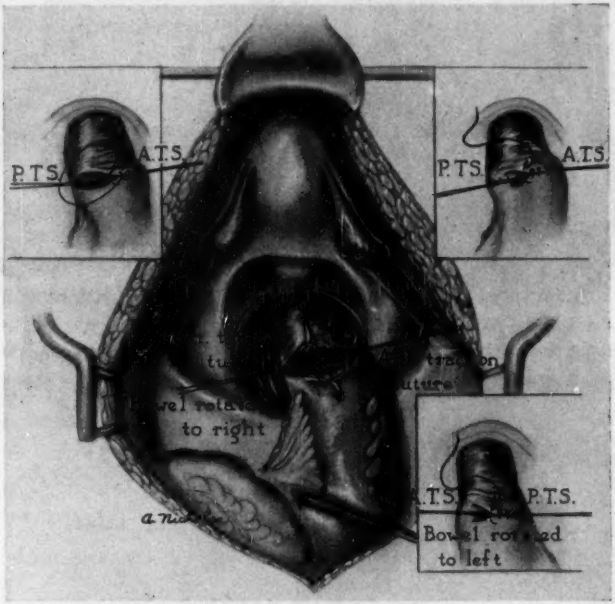

Fig. 2.—Technique of open anastomosis of the sigmoid to the rectum.

bowel is divided between clamps, and a rubber-shod clamp is applied to the proximal segment to prevent soiling. The crushing clamps are then removed, and traction sutures are placed anteriorly and posteriorly to unite the margins of the bowel openings. With the traction sutures the bowel segments are rotated to the right.

21. Maes, U., and Essrig, I. M.: Some Reflections on Surgical Principles in Treating Cancer of the Colon and Rectum, Ann. Surg. **130**:1008 (Dec.) 1949.

22. Gunkler, W. A., and Pearse, H. E.: Operative Management of Carcinoma of the Colon: Is Proximal Drainage of Unobstructed Colon Necessary? Surgery **26**:499 (Sept.) 1949.

23. Rosemond, G. P.; Burnett, W. E., and Cooke, F. N.: One Stage End-to-End Anastomosis of the Colon: An Analysis of the Complications in 79 Cases with a Comparison of Open and Aseptic Types of Anastomoses, Surg., Gynec. & Obst. **88**:209 (Feb.) 1949.

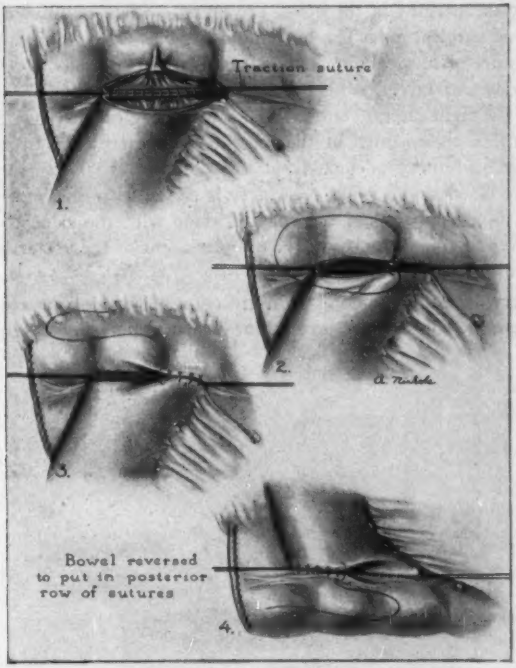

Fig. 3.—Technique of open ileocolostomy used for resections of the right portion of the colon.

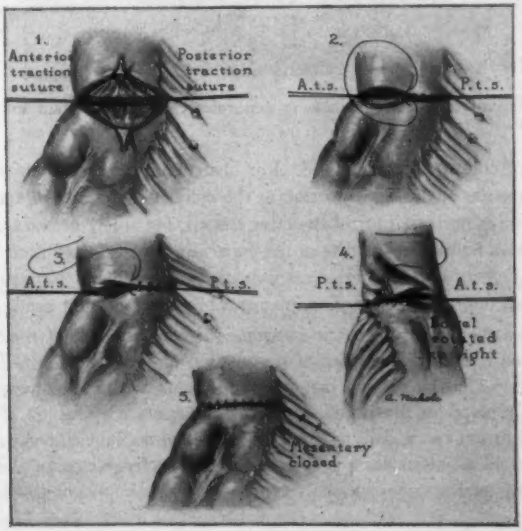

Fig. 4.—Technique of open anastomosis of the sigmoid.

The right lateral margins of the bowel are united with a continuous lock stitch of no. 00 chromic surgical gut. The left lateral margins are united with a lock stitch or Connell suture of surgical gut. Lembert or Halsted sutures of 0000 silk are used for the seromuscular layer. With the traction sutures the bowel is then rotated to the left, and the right lateral seromuscular sutures are placed (fig. 2). Additional inverting sutures are inserted at the mesenteric border when necessary to unite the bowel and mesentery adequately at this point in order to guard against any damage to the blood supply. The mesentery is closed with interrupted silk sutures. Resection of other portions of the colon is done with the same technique, using traction sutures to rotate the bowel for the placement of the posterior row of seromuscular sutures (figs. 3 and 4).

Preliminary cecostomy is done for obstruction of the transverse colon, and preliminary transverse colostomy is favored for obstruction of the left part of the colon.

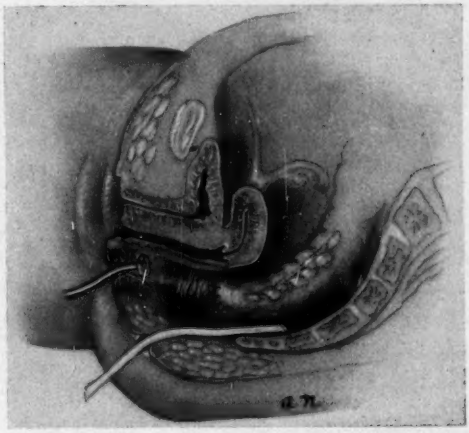

Fig. 5.—Sagittal view of pelvis showing mushroom catheter in rectum and presacral drain used for low anastomoses.

Complemental colostomy is not used. For obstruction in the cecum or the ascending colon resection of the right portion of the colon is done in two stages. The two stage operation is preferred for obstructive lesions, not solely because of the obstruction of the small bowel but because of the generally depleted condition of the patient. At the first stage an open ileotransversecolostomy is made and 10 days to two weeks later the right colon is resected. Complemental ileostomy is not used.

A Wangensteen type of gastric suction is used. The use of the Miller-Abbott tube is advised if there is evidence of obstruction of the small bowel. A mushroom catheter is placed in the rectum just inside the anus at the beginning of the operation and left in place for five or six days after the operation (fig. 5). The mushroom catheter is cleansed twice daily with 50 to 60 cc. of sodium chloride solution. For low rectosigmoid anastomoses a presacral drain is preferable to an abdominal drain. The indwelling gastric tube is usually removed on the second or third postoperative day.

SUMMARY OF OUR RESULTS

A series of 151 consecutive colon anastomoses is reviewed (table). There were 11 deaths, with a mortality rate of 7.2 per cent. With 102 open operations there were six deaths (5.8 per cent), with 40 closed operations there were five deaths (12.5 per cent) and with nine Mikulicz operations there were no deaths. While these numbers are too small to be of statistical significance, they suggest that the open colon anastomosis is as safe or safer than the closed or aseptic operation.

Four of the deaths could be attributed to defects in the technique of operation, two to mesenteric thrombosis in aged patients occurring on the nineteenth and

Colon Anastomoses in 151 Patients

Site of Carcinoma and Type of Procedure	Number	Postoperative Complications Nonfatal	Postoperative Complications Fatal
Right colon			
Open	27	.....	Mesenteric thrombosis
Closed	10	Fecal fistula	Coronary Cause of death unknown
Transverse colon			
Mikulicz	5	.....	.....
Open	4	Leak with pelvic abscess	.....
Closed	3	.....	.....
Splenic colon			
Open	2	Fecal fistula	Pulmonary embolus
Closed	2	.....	Gastrocolic fistula
Descending colon			
Mikulicz	2	.....	.....
Open	4	.....	.....
Closed	4	.....	Leak with peritonitis
Sigmoid colon			
Mikulicz	1	.....	.....
Open	30	Fecal fistula	Mesenteric thrombosis Pulmonary embolus
Closed	16	.....	.....
Rectosigmoid colon			
Open	6	Fecal fistula Fecal fistula	....
Closed	1	.....	Leak with peritonitis
Diverticulitis			
Mikulicz	1	.....	.....
Open	6	Fecal fistula Fecal fistula	Leak with peritonitis Postoperative hemorrhage
Closed	1	Leak with abscess	.....
Miscellaneous conditions			
Open	17	.....	.....
Closed	3	.....	.....
Total	151	Nonfatal 9, 5.9 per cent	Fatal 11, 7.2 per cent

twenty-seventh postoperative days, which may have been due to technical errors, three to cardiac or pulmonary complications and one to a gastrocolic fistula caused by an extensive carcinoma which existed prior to a palliative colon anastomosis. The cause of death in the eleventh patient is unknown.

In the group listed as "miscellaneous" in the table there were resections and anastomoses for stricture, regional ileitis and fistula. Other operations were colon anastomoses following former resections of the colon and resections and anastomoses for closure of colostomies.

These operations were done by both staff surgeons and resident surgeons on private and ward patients.

COMMENT

In the last 20 years there has been a decrease in mortality and morbidity with all types of colon resection and anastomosis. The majority of surgeons prefer the one stage resection with the closed (aseptic) or open method of anastomosis. With improved methods of preoperative preparation of the patient, better anesthesia and the use of antibiotics, one stage resection with open anastomosis is growing more popular. We are impressed with the use of the term "so-called aseptic anastomosis" found in recent literature, which warrants the assumption that there is no completely aseptic type of colon anastomosis. In 1937 the expression came from Allen that "the more or less aseptic methods as opposed to open anastomosis are strikingly superior." In 1947 Allen reversed his opinion and expressed a preference for the open anastomosis.

There is general agreement that a preliminary cecostomy or colostomy is advisable when the colon is completely obstructed. There is still disagreement concerning the advisability of preliminary or complemental colostomy for resections of the unobstructed colon. Recent opinions of several surgeons indicate that these procedures are not necessary.

We do not pretend to pass on the merits of the use of chemotherapeutic agents in the preparation of the colon for operation. Poth's [24] (1945) observations on the value of the sulfonamides are convincing. He believed that the changes in technique are insufficient to account for the better results of colon surgery in the last 10 years and ascribed the lower operative mortality largely to improvements in preoperative and postoperative care. In a study of the effect of antibiotics on the intestinal bacterial flora in man, Dearing and Heilman [25] (1950) found that aureomycin was more effective than succinylsulfathiazole (sulfasuxidine®), phthalylsulfathiazole (sulfathalidine®) or dihydrostreptomycin. Other intestinal antiseptics are being developed. Recently Pulaski, Connell and Seeley [26] (1950) have reported their results with aluminum pectinate, glucuronolactone and polymyxin. These authors report some promising results with these new antibiotics. In a letter to the editor of the *Annals of Surgery,* commenting on sterilization of the intestinal tract by antibiotics, Lockwood [27] (1950) said that "it must be conceded that there is no adequate proof that the incidence of complications and morbidity has been significantly influenced by this practice." As long as such drugs may be of value, and harmful effects to patients are minimal, we believe that they should be used.

The well known criteria for any successful anastomosis should be emphasized. They are (1) accurate approximation of serous surfaces, (2) absence of tension or strain on the suture line when the operation is completed, and (3) careful preservation of blood supply to the bowel at the site of the anastomosis. These principles should be repeated often and always impressed on young surgeons.

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24. Poth, E. J.: Succinylsulfathiazole and Phthalylsulfathiazole in Surgery of the Colon, Surgery **17**:773 (June) 1945.

25. Dearing, W. H., and Heilman, F. R.: The Effect of Aureomycin on the Bacterial Flora of the Intestinal Tract of Man: A Contribution to Preoperative Preparation, Proc. Staff Meet., Mayo Clin. **25**:87 (Feb. 15) 1950.

26. Pulaski, E. J.; Connell, J. F., Jr., and Seeley, S. F.: Sterilization of the Intestinal Tract by Antibiotics and Supplemental Agents, Ann. Surg. **132**:225 (Aug.) 1950.

27. Lockwood, J. S.: Letter to the Editor, Ann. Surg. **132**:319 (Aug.) 1950.

In most cases postoperative distention may be controlled by simple gastric suction. Use of the Miller-Abbott tube is recommended if there is obstruction of the small bowel. A mushroom catheter inserted just inside the anus is adequate for drainage and irrigation after resection of the lower portion of the sigmoid and the upper part of the rectum.

CONCLUSIONS

We believe that the open method of colon anastomosis results in as low a morbidity and mortality as does the closed method.

The technique of anastomisis by the open method is less cumbersome and more accurate than the closed method and produces a larger stoma.

Regardless of the type of anastomosis used, peritonitis does not result as frequently from soiling of the peritoneum at operation as it does from subsequent leakage due to defects in technique.

Primary one stage resection and open anastomosis of the colon are safe for any portion of the colon without preliminary or complemental colostomy unless obstruction exists or when perforation and infection at the site of the tumor make primary resection hazardous.

The Mikulicz and obstructive types of operation should not be completely discarded. They are useful techniques for certain types of lesions, particularly when there is pericolic infection or partial obstruction with thickening and edema of the bowel wall not completely relieved by preliminary colostomy.

DISCUSSION

Dr. Claude J. Hunt, Kanas City, Mo.: I want to congratulate the authors on an interesting and informative presentation. They have made a plea for the open anastomosis in surgery of the large bowel, and it is to this that I wish to give my few words of support. We have all experienced the evolutionary process of colon surgery. We have used the Mikulicz operation, which in reality is a splendid procedure in certain cases. It was a useful operation before the days of chemotherapy and standardized technic. It is not as frequently used as formerly because we have learned that resection and primary anastomoses can be carried out successfully and the patient subjected to only one surgical procedure and one hospital expense.

There are some definite requirements, as mentioned by Dr. Orr, that are essential for primary resection and anastomosis, as follows: (1) there should be no obstruction; (2) there should be a clean bowel; (3) there should be no tension on the site of the anastomosis, and (4) there should be no compromise with the blood supply. If these four essentials are observed, the tragedies resulting from primary anastomosis will not exceed those from anastomoses by the closed method or the procedures of stage operation according to the Mikulicz technic.

There are definite advantages to an open anastomosis. The surgeon can accurately see where to place the sutures. He can infold a minimal amount of tissue, making the diaphragm very small, and he likewise can see and inspect the two open ends of the bowel for adjacent polyps. We have found such polyps to be frequently present, and we were able, by this method, to excise them, which would not have been possible had the procedure been carried out by a closed method of anastomosis.

We do not believe that open anastomosis with a bowel properly prepared increases the danger of peritonitis. We believe that peritonitis results from leakage, necrosis of tissue and conditions unsuitable for resection and primary anastomosis.

We use about the same technique that Dr. Orr has described, namely, two rows of sutures, the outer of silk, interrupted, and the inner of 00 chromic surgical gut, the posterior row of surgical gut being a continuous lock stitch and the anterior row being an infolding Connell stitch with the sutures placed at the margin of the bowel, making a very small diaphragm and a wider anastomosis.

DR. CHARLES W. MAYO, Rochester, Minn.: I shall speak in support of what Dr. Orr has said in connection with the open anastomosis. I should like to emphasize the point that Dr. Hunt made, namely, that one of the additional advantages of the open anastomosis is the finding of any polyps that may be present in the proximal portion of the bowel. Particularly is this true of the sigmoid. In 12 instances this year I have found an adjacent polyp. If I had made a closed anastomosis it would have meant that the patient would have been back very soon with a so-called recurrence at the line of anastomosis.

When a lesion occurs in the rectum or sigmoid, where it can be reached with the sigmoidoscope, if there is any evidence of obstruction it has been our practice at the clinic not to carry out roentgen ray examination of the colon until the patient comes back for reexamination in six months. Consequently, one could easily miss polyps in the proximal portion of bowel above the growth. In connection with the open anastomosis, one should never make an anastomosis in a crushed piece of bowel.

An advantageous procedure which is simple and can be done at the conclusion of the operative procedure before the patient is taken off the table (I have said this before and I say it again) is thorough dilation of the anus. This eliminates the necessity of keeping a rectal tube in place and also keeps retention of gas down to a minimum.

FAMILIAL POLYPOSIS OF THE COLON

W. S. DYE, M.D.
G. A. OLANDER, M.D.
C. W. MONROE, M.D.
AND
J. H. OLWIN, M.D.
CHICAGO

FAMILIAL polyposis of the colon is not a common disease, and the number of cases observed by a single surgeon during his lifetime cannot be large. In 1948 Hoxworth and Slaughter [1] stated that since 1930 only 28 case reports of patients who had undergone total or subtotal colectomy for this condition had been reported by American surgeons. The authors added seven of their own. Jones,[2] also in 1948, reported on 22 patients, seven of whom had undergone total or subtotal colectomy. In the same year Cattell [3] reported on 18 patients similarly treated, but he did not present the case reports. Recently, Black and Hansbro [4] reported 41 cases covering the period from 1939 to 1949. Most authors agree that if the condition is left untreated, it will invariably end fatally as a result of malignant degeneration. The rarity of the disease in elderly patients is testimony to this fact. Inasmuch as the entire colon is involved in the majority of cases, treatment at the present time consists of either total or subtotal colectomy with ileosigmoidostomy and fulguration of the polyps in the lower segment. Since the present type of surgical attack is, for practical considerations, relatively recent and because of the comparative infrequency of the disease, it is important, as emphasized by Hoxworth and Slaughter, that reports of individual cases be recorded, in order that treatment of the condition may be properly evaluated over a period of time.

It is the purpose of this paper to present 11 cases of familial polyposis surgically treated at the Hines Hospital from 1941 to 1950.

From the Surgical Service of the Veterans' Administration Hospital, Hines, Ill.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

Sponsored by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are the results of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

1. Hoxworth, P. I., and Slaughter, D. P.: Polyposis (Adenomatosis) of the Colon, Surgery **24**:188-211 (Aug.) 1948.

2. Jones, T. E., and Turnbull, R. B., Jr.: Familial Polyposis of the Colon: Diagnosis and Treatment, S. Clin. North America **28**:1171-1184 (Oct.) 1948.

3. Cattell, R. B.: Surgical Treatment of Polyps of the Large Intestine, Am. J. Surg. **76**: 733-747 (Dec.) 1948.

4. Black, B. M., and Hansbro, G. L.: The Treatment of Familial Polyposis of the Colon, S. Clin. North America **30**:1013-1023 (Aug.) 1950.

CASE 1.—A 43 year old white man was admitted to the hospital on June 12, 1941, with the complaint of pain in the lower part of the back for three months and diarrhea for two months prior to his admission. Physical examination revealed a well nourished white man with no abnormalities except a polypoid mass on the anterior wall of the rectum, approximately 5 cm. proximal to the anal orifice. Sigmoidoscopy revealed multiple sessile and pedunculated polyps of the rectum and the lower portion of the sigmoid. Laboratory examinations gave essentially normal findings except for occult blood in the feces. An air contrast barium enema revealed numerous polyps throughout the colon. The patient deferred surgical treatment until October 1941, when an exploratory laparotomy was done and carcinoma in the midportion of the transverse colon was found. Another carcinoma was found in the cecum, at the base of the appendix. At this time a right hemicolectomy was performed, with an ileostomy. Microscopic examination of the lesions showed adenocarcinoma. In November 1941 the patient underwent an abdominoperineal resection, the specimen showing numerous polyps, three of which revealed

Fig. 1.—Familial polyposis as seen on roentgenogram following air contrast barium enema.

adenocarcinoma. In December 1941 a resection of the remaining left portion of the colon was performed. No malignant changes were found in this specimen. The patient was asymptomatic until May 1942, when pains developed in the lower part of the abdomen associated with vomiting. An exploratory laparotomy in June of 1942 revealed multiple adhesions and abdominal metastases. The patient died on Aug. 26, 1942.

Comment.—This patient gave no definite familial history of polyposis.

CASE 2.—A 23 year old white man was admitted to the hospital on Oct. 31, 1945, with the complaint of intermittent diarrhea and abdominal cramps since June 1944. He had also noticed blood in his stools and a loss of 40 pounds (18 Kg.) in weight during the year and a half prior to his admission. Physical examination revealed the presence of multiple polyps in the rectum and the lower part of the sigmoid, demonstrated on proctoscopy. An air contrast barium enema revealed multiple polyps throughout the entire colon. The patient had moderate anemia, and examination of the stools for ova and parasites gave negative results. Right

hemicolectomy and ileostomy were carried out on Jan. 25, 1946. Pathologic examination revealed malignant degeneration in several polyps in the transverse colon. The patient deferred further surgical treatment until May 25, at which time the isolated polyps in the rectum were fulgurated. On June 10 a left hemicolectomy and an ileosigmoidostomy were performed. The patient was discharged on July 12, 1946, and a recent follow-up examination revealed that he was doing well and gaining weight.

Comment.—There was no evidence of a familial history of the disease in this case. The number of polyps in the rectum was few, and, compared to the others presented, the patient could be followed with relative safety.

Fig. 2.—Typical diffuse polyposis seen in the cecum in case 1. The polyp outlined by the slip of paper showed malignant degeneration.

CASE 3.—A 31 year old white man was admitted to the hospital on Oct. 19, 1946, with the complaint of intermittent diarrhea since 1942 and occasional cramplike pain in the abdomen. Physical examination revealed a well nourished white man with multiple small polyps in the lower portion of the rectum on sigmoidoscopy. An air contrast barium enema revealed multiple polyps throughout the entire colon. In this patient the first operative procedure was fulguration of the rectal polyps in multiple stages. The patient deferred surgical treatment, and it was not until Oct. 8, 1947, that the first definitive operation, namely, a left hemicolectomy with sigmoid and transverse colostomies, was performed. On November 26, a right hemicolectomy was performed and the ileum was anastomosed to the sigmoid distal to the colostomy. The colostomy stoma subsequently was closed. Follow-up examination revealed the lower segment to be free of polyps. The pathologic examination of the resected specimens did not reveal any malignant changes. The patient is still having several loose stools a day and occasionally has symptoms of partial obstruction of the small bowel.

Comment.—The patient's paternal grandfather, his two sisters and five brothers all died in their early thirties of a condition which at that time was called "tuberculosis of the intestine." His grandfather had six children, three of whom died of cancer of the lower part of the bowel at the ages of 40, 44 and 45. In addition, it was found that an aunt of the patient on his mother's side had a carcinoma of the bowel at the age of 40. It was found that this woman had three distinct carcinomas of the sigmoid. The patient's maternal uncle died at the age of 45 of carcinoma of the bowel. The patient's mother also died of carcinoma of the lower part of the bowel.

CASE 4.—A 28 year old Negro was admitted to the hospital on Aug. 9, 1947, with the complaint of gas pains in the lower part of the abdomen, particularly when he was constipated. A month prior to his admission diarrhea developed with blood in the stools. Sigmoidoscopy revealed multiple polyps, and a barium enema revealed a constricting lesion at the rectosigmoid junction. Further studies of the entire colon were impossible because of the obstructive lesion. Laboratory examinations showed mild secondary anemia. On September 3, an exploratory laparotomy was performed and a combined abdominoperineal resection, with a transverse colostomy, was carried out. Examination of the removed segment of the rectum and sigmoid revealed three distinct carcinomas. Examination through a sigmoidoscope of the proximal and distal loops of the colostomy revealed multiple polypi. The colectomy was completed on October 6, at which time a permanent ileostomy was accomplished. The patient made an uneventful recovery and was discharged on November 28. He was readmitted in November 1948, because of obstructive symptoms, and at laparotomy several adhesive bands were released. At a recent follow-up examination he had gained weight and appeared to be doing well.

Comment.—There was no familial history of polyposis in this case.

CASE 5.—A 33 year old white man was admitted to the hospital on July 4, 1947, with the complaint of diarrhea for two and one-half years and occasional blood in the stools. A barium enema given by his private physician revealed a tumor of the descending colon. There had been no weight loss. Sigmoidoscopy revealed two small sessile polyps. Roentgenologic studies revealed an obstructive lesion of the descending colon. Laboratory examination revealed essentially normal findings. On July 28 an exploratory laparotomy was done, at which time the tumor of the sigmoid colon was resected and a primary anastomosis was performed. The resected segment revealed an adenocarcinoma and multiple small polyps. On November 10 a left hemicolectomy and ileosigmoidostomy were performed; the proximal transverse colon was anastomosed to the sigmoid colon proximal to the ileosigmoidostomy. On February 9 a right hemicolectomy was performed. The surgical specimens revealed multiple polyps throughout the colon, with no malignant degeneration. The small polyps in the rectum were fulgurated, and the patient was discharged on February 20. At a recent examination the patient appeared to be in good health, he had gained weight and was having approximately two bowel movements a day. Sigmoidoscopy revealed no pathologic changes in the lower segment.

Comment.—In this case also there was a familial history of polyposis. His father died in 1948 at the age of 65 of carcinoma of the large bowel. One brother had multiple polyposis of the colon and underwent total colectomy in 1947. Another brother has multiple polyposis of the colon and is to undergo a colectomy; the same is true of a sister.

CASE 6.—A 25 year old white man was admitted to the hospital on Aug. 20, 1947, with the complaint of diarrhea for 10 years prior to his admission, occasional blood in the stools and cramping pain in the abdomen. The patient had lost 30 pounds (13.6 Kg.) in the three months prior to his admission. Physical examination revealed numerous polyps in the rectum and the lower part of the sigmoid colon. An air contrast barium enema revealed multiple polyps throughout the entire colon. On September 17 right hemicolectomy and ileostomy were performed. On September 29 a revision of the ileostomy was done. On December 29 revision

of the ileostomy was again done, and it was covered with a dermatome graft. The patient deferred further surgical treatment until April 27, 1948, when the remaining portions of the colon down to the rectum were removed. He again deferred the completion of his colectomy. On October 21 an abdominoperineal resection was carried out. There was no evidence of malignant degeneration in any of the specimens. The patient was discharged on Nov. 17, 1948. A recent follow-up examination showed him to have lost some weight, but he had no other symptoms, signs or complaints.

Comment.—This patient's mother died of cancer of the rectum and his father of cancer of the stomach, both in 1942. Two brothers have polyposis. One has undergone a colostomy for inoperable carcinoma of the rectum, and the other, at the age of 40, refuses to have surgical treatment for his condition.

CASE 7.—A 21 year old white man was admitted to the hospital on Sept. 23, 1948, with the complaint of bloody diarrhea and cramping pain in the lower part of the abdomen since June 1945. The patient had lost 25 pounds (11.3 Kg.) of weight since the onset of his illness. Physical examination revealed moderate tenderness in the left lower quadrant and multiple polyps in the rectum observed on proctoscopic examination. An air contrast barium enema revealed the presence of multiple polypi throughout the colon. On Oct. 14, 1948, right hemicolectomy and flap graft ileostomy were performed. On December 15 left hemicolectomy and abdominoperineal resection were performed. The surgical specimens revealed multiple polyps throughout the colon, with no malignant degeneration. At a recent follow-up examination this patient appeared to be doing well.

Comment.—The patient's mother died at the age of 41 of cancer of the stomach. Other members of the family on his mother's side showed a tendency toward the development of cancer in their later years, type unknown. This patient underwent a total colectomy and an ileostomy, covered with a full thickness flap of skin which has been fitted with an appliance. The technique of the construction of this type of ileostomy has been described elsewhere.[5]

CASE 8.—A 27 year old white man was admitted to the hospital on Jan. 22, 1949, with the complaint of diarrhea since April 1948. He had lost approximately 10 pounds (4.5 Kg.) prior to his admission. Physical examination revealed a poorly nourished white man. Rectal examination and proctoscopy revealed polyps throughout the rectum. Laboratory examinations revealed no abnormalities except for moderate secondary anemia. An air contrast barium enema revealed multiple polyps throughout the entire colon. On March 15, 1949, the patient underwent an ileosigmoidostomy and right hemicolectomy. On April 19, 1949, left hemicolectomy was performed. Since then, he has been subjected to multiple stage fulguration of the polyps in his rectum. There was no malignant degeneration in any of the surgical specimens or in the biopsy specimen.

Comment.—The ideal procedure in this patient would have been a total colectomy, since the polypi in the rectum were so numerous. However, the patient refused to allow such a procedure. There is no definite familial history of the disease in this case.

CASE 9.—A 35 year old white man entered the hospital on Feb. 18, 1949, with the complaints of abdominal pain and diarrhea for six years prior to his admission. He had on occasion noted blood in his stools and had lost approximately 15 pounds (6.8 Kg.) of weight in the year prior to his admission. Sigmoidoscopy revealed the entire rectum to be studded with polyps, many of which were inflamed. Fluoroscopy of the stomach revealed a duodenal ulcer. An air contrast barium enema revealed multiple polypi throughout the entire colon and in addition what appeared to be a constricting lesion in the region of the proximal sigmoid.

5. Monroe, C. W., and Olwin, J. H.: Use of an Abdominal Flap Graft in Construction of a Permanent Ileostomy, Arch. Surg. **59**:565-572 (Sept.) 1949.

Sigmoidoscopy was again performed, and tissue for biopsy obtained at 20 cm. showed the presence of adenocarcinoma. An abdominoperineal resection including the sigmoid colon was performed on March 14, 1949, and the specimen revealed a carcinoma of the sigmoid together with many polyps. A right hemicolectomy was performed on May 12, 1949, and an ileostomy, covered with a full-thickness skin flap,[5] was constructed. On June 17, 1949, a left hemicolectomy was done, completing the removal of the entire colon. Nineteen months after excision of the carcinoma the patient showed clinical evidence of metastases.

Comment.—There was a questionable familial history in this case. The patient stated that his father and an uncle died of cancer of the bowel. The sequence of procedures was determined by the presence of carcinoma in the sigmoid colon.

Case 10.—A 30 year old white man was admitted to the hospital on Feb. 13, 1950, his only complaint being an increase in the number of stools daily. Two years earlier he had been told that he had polyps of the lower part of the bowel. Sigmoidoscopy revealed many polyps in the

Fig. 3.—Ileostomy covered with flap graft of skin. The technic of its construction is described in an earlier paper.

rectum. Biopsy of two polyps was done, and they were found to be benign. An air contrast barium enema revealed diffused polyps of the sigmoid and the descending colon. On March 7, 1950, the patient went to surgery, a subtotal colectomy with ileosigmoidostomy being contemplated. However, the presence of many polyps at the intended line of anastomosis led to the decision to do a complete colectomy. Accordingly, an ileostomy was performed, and the perineal part of the colectomy was completed three days later. Microscopic examination of many of the polyps diffusely present throughout the large bowel revealed no malignant growths.

Comment.—This patient's mother and maternal grandfather both died of carcinoma of the colon. His mother died at the age of 31. One brother is living and well. Two sisters are living, both of whom have polyposis of the colon.

Case 11.—A 31 year old man was admitted to the hospital on July 17, 1950, complaining of recurrent bouts of rectal bleeding, abdominal pain and distention since 1943. He stated that in 1944 rectal polyps were removed through a proctoscope. Since that time he has continued

Data on Eleven Cases of Familial Polyposis of the Colon

Case No.	1	2	3	4	5	6	7	8	9	10	11
Age	43	23	31	28 Negro	33	25	21	27	35	30	33
Familial history of the disease	No	No	Yes	No	Yes	Yes	Yes	No	?	Yes	Yes
Complaints:											
Diarrhea	+	+	+	+	+	+	+	+	+	+	+
Cramping pain	..	+	+	+	..	+	+	..	+	..	+
Blood in stool	..	+	..	+	+	+	+	..	+	..	+
Loss of weight	..	+	..	..	..	+	+	+	+	..	+
Portion of colon involved	Entire	Entire	Entire	Entire	Entire	Entire	Entire	Entire	Entire	Entire	Entire
Carcinoma present at time of operation	Multiple sites	Multiple sites	No	Multiple sites	Single site	No	No	No	Single site	No	No
Sites of carcinoma	Cecum, transverse colon, rectosigmoid	Transverse colon	..	Sigmoid—1 Rectum—2	Sigmoid colon	..	..	..	Sigmoid colon	..	..
Type of operation	Total colectomy	Subtotal colectomy	Subtotal colectomy	Total colectomy	Subtotal colectomy	Total colectomy	Total colectomy	Subtotal colectomy	Total colectomy	Total colectomy	Subtotal colectomy
Time elapsing since surgery	9 yr.	4 yr.	3 yr.	3 yr.	2 yr.	2 yr.	2 yr.	1 yr.	1 yr.	9 mo.	1 mo.
Status	Dead of carcinoma	Living and well	Living and well	Living and well	Living and well	Living and well	Living and well	Living and well	Living and well	Metastases	Living and well

to have abdominal cramps, distention, weakness and alternating bouts of constipation and diarrhea. Sigmoidoscopy revealed diffuse polyposis of the rectum and the sigmoid colon. An air contrast enema revealed polyposis of the entire colon. On August 16 and again on August 31 fulguration of the polyps in the rectum was carried out. He was discharged on September 11, with instructions to return in six weeks for a definitive operation. He was readmitted on October 23, and on November 1 a resection of the terminal portion of the ileum and the entire colon down to the sigmoid was carried out and bowel continuity reestablished by means of an ileosigmoidostomy. The patient's postoperative course was uneventful, and he was discharged, without symptoms, on November 15.

Comment.—The familial history in this instance was limited to the patient's statement that his mother had died of cancer of the colon. This case is also an instance in which fulguration of the rectal polyps was carried out prior to resection of the colon.

COMMENT

An excellent summary of the surgical management of familial polyposis has been given by Hoxworth and Slaughter. The high incidence of carcinoma developing in cases of polyposis has necessitated a radical surgical approach, and the difference of opinion in all discussions of treatment is concerned primarily with the management of the rectal segment. In those instances in which the lower sigmoid and the rectum are diffusely covered with polyps or if it is unlikely that after operation the patient can be closely followed, total colectomy is considered the procedure of choice. Another factor favoring this type of surgical treatment is the relatively high incidence of carcinoma in the sigmoid colon and the rectum. If the polyps in the lower segment are not too numerous and if the patient can be closely followed after the operation, subtotal colectomy with ileosigmoidostomy and fulguration of the remaining polyps may be carried out. Refusal of the patient to submit to removal of the rectum may be another reason for subtotal colectomy. Inasmuch as occult carcinoma may be present in many cases of polyposis, resection of the colon should as a rule be accomplished as soon as possible after the diagnosis of polyposis has been made and fulguration carried out later. The fact should not be overlooked that early carcinoma developing in a previously fulgurated mucosa might, because of scar tissue, be difficult to recognize, and it should again be emphasized that the surgeon who leaves behind the lower segment must be alert for any significant change in that potentially carcinoma-bearing area. Whether it is wise to leave it behind, even with careful follow-up, is a point that cannot at the present time be definitely settled. Too few cases of the disease have been reported, and an insufficient period has elapsed since the present type of surgical attack was instituted. It is apparent that a larger experience with the surgical treatment of this disease, along with follow-up of the patients, will be necessary before a statistically accurate appraisal can be made.

SUMMARY

The case histories of 11 patients surgically treated for familial polyposis of the colon have been presented. All the patients were men and ranged in age from 21 to 43, the average age being 29. One patient was Negro, and the others were white. A familial history of the disease was present in six instances and questionable in a seventh. Polyposis was present throughout the entire colon in all cases. Carcinoma was present at the time of operation in five cases, and in three

of the cases there were multiple sites. The sigmoid colon and the rectum were the sites of cancer in four cases.

Total colectomy was carried out in six cases. In five cases subtotal colectomy with ileosigmoidostomy and fulguration of the lower segment was done. One patient died of metastatic carcinoma ten months after surgical treatment. One other has clinical evidence of metastasis 19 months after operation. Nine patients are apparently free of disease.

The cases are presented with the idea of adding to the sum total of cases in the literature in order that over a period of time proper evaluation may be made of the present types of treatment used for this important though relatively rare disease.

DISCUSSION

DR. ROBERT L. SANDERS, Memphis, Tenn.: One phase of this subject which is seldom mentioned in the literature is the restoration of the continuity of the intestinal tract after the colon has been removed and the rectum has been given a prolonged rest. The thought I have in mind is best illustrated by one of our experiences.

Two sisters, both in the fifth decade of life, came to us with familial polyposis. We operated on one, performing a one stage subtotal colectomy, with anastomsis of the terminal portion of the ileum to the lower sigmoid. The rectum contained only a few polypi, all easily fulgurated. The other sister had so many polypi and so much edema and ulceration in the rectum that we felt certain she would require a total colectomy, including removal of the rectum. For this reason, an ileostomy was established and a subtotal colectomy performed as the first stage of the procedure. The blind end of the sigmoid was left in the lower end of the incision in preparation for the abdominoperineal resection which we planned to do two or three months later.

Both patients returned from time to time for fulguration of other polypi in the rectum, the one who underwent the colectomy meanwhile being much envied by the one in whom ileostomy had been performed. Both progressed well, however, and eventually the rectum of the one who had the ileostomy was as satisfactory as that of the other. At her insistence, therefore, after the elapse of a year without the development of further rectal polypi, we anastomosed the ileum to the lower sigmoid. Two years have passed since the operation and the patient still has a smooth well functioning rectum.

This case demonstrates the fact that one should not be too eager to remove the rectum in these cases. Rather, by frequent observation and control of rectal polypi by fulguration, one may occasionally be able to reestablish the continuity of the intestinal tract without sacrificing the rectum.

DR. R. RUSSELL BEST, Omaha: At the present time it is my opinion that a patient with polyposis of the colon and rectum should not be subjected to a permanent colostomy. I appreciate that this subject is somewhat debatable. We may divide cases with polyposis of the colon or rectum into two groups, namely, those with polyposis without malignant changes and those with polyposis associated with a malignant process. I refer particularly to a malignant process in the regions of the rectum and the rectosigmoid.

In a patient with polyposis of the rectum and colon in which no malignant changes are present, the rectal polyps and adenomas may be removed with the electric cutting loop or by fulguration, going as high into the rectum as possible or even into the rectosigmoid. After the rectum has been cleared of polyps, colectomy can then be done in one stage and the terminal portion of the ileum anastomosed to the rectal stump. I feel confident that if a doctor was given a choice in his own case he would plead for preservation of the anal sphincter. Of course these patients must be followed periodically for recurring or new polyps.

When it comes to a patient with polyposis and also a malignant process in the rectum, we have a more debatable problem. Here again, if the malignant lesion is above the 4 inch (10 cm.) level, we favor eradicating the rectal polyps and following this procedure with colectomy and radical rectosigmoidectomy. When the lesion is below the 4 inch level, the problem is still more debatable. When the lower margin of the malignant lesion is at the 3 inch level, it is

our opinion at the present time that the lower polyps should be destroyed, the entire colon removed and then a rectosigmoidectomy accomplished by the combined abdominal and posterior route, anastomosing the ileum to the short rectal stump.

One should thoroughly fulgurate the polyps before removing the colon, and the anastomosis must be of the open type so that all polyps will have been removed from the lower rectal segment and near the line of anastomosis. It is interesting to follow these cases of low anastomosis by proctoscopic examination. Practically always there is an irregular, shaggy line at the site of anastomosis; in fact, it almost appears polypoid at times. One will want to interpret this irregularity at the site of anastomosis as recurrent polyps or a recurrent malignant process. Further observations or even a biopsy is indicated at times to make sure that one is not dealing with recurring malignant growths or polyps of a true nature.

Concerning the first paper on this morning's program (by Dr. Kittle and others), reference was made to the open and closed types of anastomosis. In our opinion, in colon resections above the rectosigmoid it does not make any difference which type is used. It is just a matter of which technic is more convenient for the individual surgeon. I most frequently make the anastomosis over the Rankin clamp, as I find this method more convenient. For anastomosis in the rectum, which is accomplished either through the abdomen and low in the pelvis or through the posterior route, I believe that an open type of anastomosis is indicated, particularly when one is dealing with malignant changes. With the open method of anastomosis one can be sure that the bowel is definitely transected below the tumor margin.

In regard to decompression above an anastomosis and drainage of the abdomen or pelvis, in our cases of rectosigmoidectomy with anastomosis, whenever an anastomosis is made in the rectum or low in the sigmoid we do a complementary cecostomy. If the peritoneal floor has been incised and structures freed from the hollow of the sacrum, we always establish drainage posteriorly by a small incision along the coccyx, the drain having been placed in the hollow of the sacrum before the abdomen is closed.

DR. J. W. THOMPSON, St. Louis: I wish particularly to discuss the problem of familial polyposis. It has been my privilege to attend a family residing in southern Illinois, among whom I have observed approximately 10 persons with this condition. I presented a table illustrating the hereditary lines of transmission in this family in the *Surgical Clinics of North America* (**20**:1317 [Oct.] 1490).

In view of the remarks of Dr. Chambelson yesterday at the Veterans Hospital, I believe that my own observations on this rather amazing family indicate that there is some biological determinism in the development of malignant degeneration somewhere among the myriads of polypi in these persons. Dr. Best has emphasized this point by his own observations, which apparently are in accord with mine.

The first member of this family, whom I attended more than 12 years ago, refuses to submit to a surgical operation. He has seen three of his brothers undergo radical surgical procedures. Only one of these three remains alive and well after a total colectomy. In another one cerebral metastasis developed, and he died approximately six months after total colectomy. The third underwent a total colectomy and died from complications resulting from an automobile accident.

The female members of the family, having seen the brothers undergo these terrible surgical ordeals, refused to have anything done, and, to the best of my knowledge, up to the present time none of them has had a malignant growth. Therefore, one might assume that in this particular family group the tendency to undergo malignant degeneration is a sex-linked biological determinant, which is more pronounced in the males. I am not too definite about conclusions as to what should or should not be recommended. It would seem, however, that at the first suspicion of malignant degeneration, extirpation of the colon should be seriously considered as the best possible means of eradicating a lesion which, at least presumably, will eventually cause death because of the complications of malignant degeneration of one or more areas in the colon afflicted by multiple hereditary familial polypoidosis.

DR. J. H. OLWIN, Chicago: I should like to say that the tenor of the discussion, namely, disagreement and uncertainty, is the primary reason for our presenting this paper. It is only by a detailed reporting of individual cases (and the paper to be published will contain the case reports in moderate detail) over a period that we shall be able to know what the proper treatment of familial polyposis is and whether or not, as Dr. Thompson reported in his cases, some of the patients may be wise in refusing to submit to a permanent ileostomy.

SURGICAL TREATMENT OF FAMILIAL POLYPOSIS

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ST. LOUIS

A POLYP or polypus is a smooth and pedunculated growth arising from a mucous surface; the word has its origin in the Greek adjective "polus" meaning "many" and "pous" meaning "foot." Adenomatosis may be defined as a condition in which glandular tissue becomes the seat of exuberant overgrowths and which has as its origin the Greek words "aden" meaning "gland" and "oma" meaning "tumor." Let me emphasize the fact at the onset (as many others have done) that the term "polyposis" or "adenomatosis" should be used to describe the condition under consideration in that each implies the multiplicity of the lesions.

Guptill [1] and later Hoxworth and Slaughter [2] have collected the pertinent historical facts concerning familial polyposis of the colon. Briefly they include the first report of this condition by Menzel in 1721, a second description of the condition in a 30 year old woman in 1861 and the detailed pathological data given by Virchow in 1863. It remained for Cripps [3] in 1882 to prepare the classical description of the disease and to point out its familial characteristics. The familial tendencies were further clarified and particularly emphasized by Lockhart-Mummery [4] and by Dukes, McKenney,[5] Friedell and Wakefield, Rankin and others. Hoxworth chose to designate 1930 as the year from which most of the progress dates because of Cuthbert Duke's important contribution establishing the hereditary characteristics of the disease. He also emphasized the fact that this is a particular disease from which one can expect malignant degeneration in every instance if it is allowed to progress untreated.

Dukes points out that the French have a proverb, "C'est le premier pas qui coûte"—"The first step counts most." The most important single factor in arriving at the diagnosis of familial polyposis is to think of this particular disease when con-

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Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

1. Guptill, P.: Familial Polyposis of Colon: Two Families, Five Cases, Surgery **22**:286-304, 1947.

2. Hoxworth, P. I., and Slaughter, D. P.: Polyposis (Adenomatosis) of Colon, Surgery **24**:188-211, 1948.

3. Cripps, W. H.: Two Cases of Disseminated Polypus of the Rectum, Tr. Path. Soc., London **33**:165-168, 1881-1882.

4. Lockhart-Mummery, J. P., and Dukes, C. E.: Familial Adenomatosis of Colon and Rectum: Relationship to Carcinoma, Lancet **2**:586, 1939.

5. McKenney, D. C.: Multiple Polyposis: Congenital, Heredofamilial, Malignant, Am. J. Surg. **46**:204-216, 1939.

fronted by a young adult with diarrhea extending over a long time. Our chief faults from a professional standpoint are usually those of omission rather than of commission. Once suspicions are aroused, the diagnosis can be made by means of a barium enema followed by evacuation and air injection roentgenograms. A routine barium enema is usually of no value, and too much trust cannot be placed in the contrast roentgenograms.

The symptoms and signs of this disease include bowel irregularity, diarrhea, the presence of mucus and blood in the stool and abdominal cramps and tenesmus. Any of these should warrant a digital rectal examination and a proctosigmoidoscopic examination, at which the polyps may be seen under direct vision and tissue removed with the biopsy forceps from characteristic and suspicious areas for microscopic section. In spite of a specific history and the majority of the above signs and symptoms, a certain number of proctosigmoidoscopic examinations will not reveal any suggestive lesion, and it remains for the contrast enema not only to clinch the diagnosis but in each instance to demonstrate the anatomical limitations and the extent of the disease.

Inasmuch as the disease is a specific clinical entity, with a Mendelian dominant which is transmitted by father or mother and may be inherited by children of either sex, it does not seem justifiable to consider the classification of Erdman and Morris.[6]

Helwig [7] pointed out the fact that many adenomas of the colon were histologically malignant but clinically benign. This apparent inconsistency is due to the prevalence of the disease in the second, third and fourth decades and the relatively slow rate of the malignant degeneration, and yet carcinomatous degeneration is the end result in every untreated patient. From a clinical standpoint, unless the signs of impending death from an overwhelming carcinomatosis arising in the colon are present, local malignant degeneration with involvement of the muscularis and the serosa and subsequent deformities is apparent to the trained surgeon and is properly considered at the operating table.

Most of the patients are young adults, and their general health and over-all reserve are in keeping with their years or are easily restored with multiple whole blood transfusions. The remarkable development of the present blood bank system is one of the factors that make a direct surgical attack on the disease practicable at this time. Abnormal nutritional states from hyperirritability of the intestinal tract and the varying degrees of anemia from direct blood loss in each instance respond to specific therapy.

Knotts and Poth [8] and subsequent investigators have shown the efficacy of the administration of the nonabsorbable sulfonamides in keeping the colon reasonably free from pathogens. More recently streptomycin and neomycin have been used to reduce the bacterial flora of the colon. In addition to their bactericidal and bacteriostatic action, these drugs have a specific effect on the physical characteristics of the colonic content. The normal fecal bolus is no longer present but is replaced by a soft and freely flowing stream which rapidly clears through the large bowel with a

6. Erdman, J. F., and Morris, J. H.: Polyposis of the Colon: A Survey of the Subject, Surg., Gynec. & Obst. **40**:460-468, 1925.

7. Helwig, F. C.: Rôle of the Pathologist in the Diagnosis of Polypoid Lesions of the Colon and Rectum, Am. J. Surg. **76**:728-732, 1948.

8. Poth, E. J., and Knotts, F. L.: Succinylsulfathiazole, a New Bacteriostatic Agent Locally Active in the Gastrointestinal Tract, Proc. Soc. Exper. Biol. & Med. **48**: 129-130, 1941.

cleansing action as it moves downward. Several stools every 24 hours result from this medication and have a mechanical "wiping" effect on the mucosa of the large intestine.

Zerbini [9] in our laboratory demonstrated the important role which vitamin C plays in wound healing. As the result of this work, each patient receives 1 Gm. of ascorbic acid every 24 hours for two days preoperatively and for at least six days postoperatively.

Continuous spinal anesthesia with intravenous injection of thiopental sodium (pentothal sodium®) and endotracheal administration of cyclopropane-ether with thiopental sodium induction and the addition of curare to obtain maximal muscular relaxation have been used with equal satisfaction.

A transverse subumbilical incision extending well out into each flank gives the best exposure and is the incision of choice. Accurate hemostasis of the cut edges of this incision is obtained and the abdomen thoroughly explored with the patient in the normal supine position. The large bowel is carefully inspected and evaluated. Particular attention is paid to serosal deformities indicative of underlying malignant changes, to peritoneal implants resulting from direct extension and to the presence of metastatic lesions in the liver and in the regional lymph glands. If gross malignant degeneration is present in the rectum, a combined abdominoperineal resection of the colon and rectum must be carried out, as in case 4. The amount of colon that is left behind depends entirely on the noninvolvement of the segment. If, however, a total colectomy with ileoproctostomy can be carried out, the patient is placed in the extreme Trendelenburg position, which with adequate relaxation permits the small intestine to fall away from the pelvis and the colonic areas. A site is selected in the terminal portion of the ileum 10 cm. proximal to the ileocecal valve and the small bowel clamped and divided between two thin Dennis clamps. At this site the mesentery is likewise divided and the mesenteric blood vessels ligated. The bloodless adhesions that are normally present between the sigmoid and the left lateral wall of the abdomen are divided and the sigmoid dissected free from the hollow of the sacrum.

At a level 3 cm. proximal to the peritoneal reflection on the rectum the terminal portion of the sigmoid is carefully freed and transected between clamps. If one ligates the superior hemorrhoidal and the second and third sigmoidal arteries or the inferior mesenteric artery prior to division of the sigmoid, the subsequent stages are rendered rather bloodless and the operative procedure expedited. The proximal cut end of the sigmoid is carefully covered with a rubber container and allowed to gravitate to the upper region of the abdomen. A ¾ inch (2 cm.) rubber tube is passed up through the rectum and allowed to protrude through the distal segment of the sigmoid. The proximal portion of the ileum is then rotated over to the hollow of the sacrum and two interrupted sutures of 00 chromic surgical gut used to suture the rubber tube to this area. An open type of anastomosis is then performed, particular attention being paid to accurate approximation and an inner continuous suture of 00 chromic surgical gut being used, which is later reenforced with a few interrupted mattress sutures giving serosal approximation. Traction is made on the indwelling rubber tube from beneath the drapes, and the infolding process aided materially in the fashion popularized by Dr. Balfour.

9. Zerbini, E. de J.: The Importance of Ascorbic Acid (Vitamin C) in Chest Surgery, J. Thoracic Surg. **14**:309-321, 1945.

The presence of the tube not only provides a splinting action to the anastomotic line which comes to lie at the level of the peritoneal reflection but also acts as a safety valve and removes all pressure that might result from ileus above the suture line. The end to end anastomosis eliminates all but one suture line, in contradistinction to an end to side or side to side type.

At the conclusion of the anastomosis the surgical picture is rapidly reviewed and the colectomy carried out or the ileum and sigmoid ends exteriorized if for some reason the operation should be terminated at this level. In our experience, this exteriorization has not been necessary but it is a safety measure.

The terminal portion of the ileum and the cecum are drawn to the midline and the now taut posterior parietal peritoneum incised 3 cm. lateral to the bowel margin and carried up and around the hepatic flexure. Only lacy areolar tissue is encountered, with an occasional fascial band that requires division with scissors. The right portion of the colon is then seen to hang loosely by its mesenteric leaf, with its contained blood vessels and lymph glands. The duodenum and the spermatic or ovarian vessels and the right ureter are visualized and protected from injury. The omentum is then stripped from the transverse colon unless one elects to remove the omentum with the colon because of direct extension of the disease. The ileocolic, right colic and middle colic arteries are specifically identified and ligated with silk before transection. Similarly the descending colon and sigmoid are mobilized by incising the lateral leaf of the mesentery, and the left colic and remaining sigmoidal branches are ligated and divided. The splenic flexure is visualized by applying traction and the phrenocolic ligament ligated and divided, thus completely freeing the colon. No particular attempt has been made to reperitonealize the surfaces bared of peritoneum, and no complications have arisen from this procedure suggested by Brunschwig and his co-workers.[10]

The abdomen is closed with interrupted buried figure-of-8 mattress sutures[11] of no. 30 stainless steel wire, as previously described, with a series of subcutaneous and subcuticular running stainless steel sutures, which are removed. One of our residents[12] suggested that the last suture be begun with twice the calculated length of suture material. After the running suture has been placed the used part is pulled through and cut off, leaving the fresh and unhandled sutures in the tissue, which makes for easy removal (figs. 1 and 2).

Obviously the commonest complication will arise from the loss of fluids and electrolytes during the first week after a total colectomy. Large amounts of sodium and potassium as well as fluids are inevitably lost and are replaced with Hartmann's solution. No references, however, are found to the use of salted peanuts in the postoperative diet, an item which has been found to be invaluable. It provides electrolytes and proteins, has a "blotting" action similar to a buffer and reduces the number of stools per day.

The indwelling rectal tube is spontaneously extruded on about the eighth postoperative day when the chromic surgical gut retention sutures have undergone autolysis.

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10. Robbins, G. F.; Brunschwig, A., and Foote, F. W., Jr.: Deperitonealization: Clinical and Experimental Observations, Ann. Surg. **130**:466-479, 1949.

11. Walton, F. E.: The Prevention and Treatment of Wound Dehiscence, Arch. Surg. **57**:217-226 (Aug.) 1948.

12. Dr. John Bassett.

Fig. 1.—Drawing of the type of stitch used.

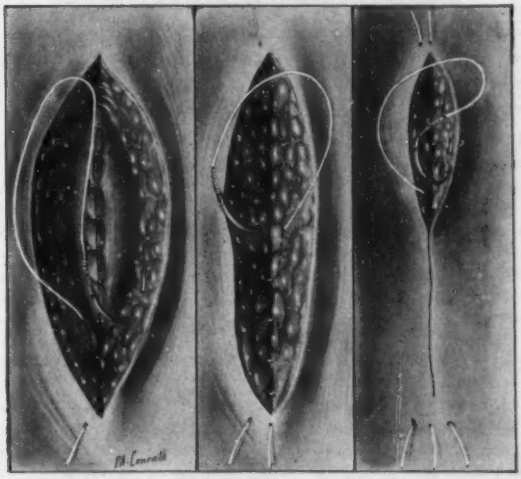

Fig. 2.—Drawing of the type of closure popularized by Dr. Frederick Coller.

From an anatomical standpoint it has been clearly shown that too much attention has been paid to the so-called critical point of Suedeck. Any one who has performed anterior resection of either the lower part of the sigmoid or the upper part of the rectum has found that the blood supply from the inferior mesentery artery is not essential to the survival of either the rectal or the lower sigmoidal segment because of the anastomoses with branches of the hypogastric artery. When glands involve the root of the mesentery, the inferior mesenteric artery can be divided at its root before it gives off the left colic and the sigmoidal arteries, the superior hemorrhoidal artery thus being sacrificed.

The specific operative procedure of ileosigmoidostomy was reported by Lilienthal [13] in 1900, although this operation was followed by a subtotal colectomy three months later. Dr. Evarts A. Graham performed a one stage operation such as has been described today, with a resection over a tube in November 1925 at Barnes Hospital on a 16 year old girl with polyposis of the colon. Gardner [14] recently reported three cases of polyposis of the colon in which one stage colectomy and ileorectal anastomosis were carried out.

The recent experimental work and clinical application by Ravitch [15] and his associates in utilizing an anal ileostomy with preservation of sphincteric function in patients requiring a total colectomy provides the ideal operation and eliminates the rectal segment that remains behind in ileoproctostomy. The fact that polyp-bearing tissue is purposely left behind in an ileoproctostomy has been a valid criticism of this procedure from the standpoint of sound surgical principles dealing with potential malignant processes, a point which Bartlett and Peck [16] discussed in a recent paper. On the other hand, no difficulty has been encountered to date in observing and destroying occasional polyps that have developed in the patients presented in this communication.

REPORT OF CASES

Two families, consisting of a parent and two siblings in each instance, have been under my care, and their cases emphasize some of the points being discussed. Five of them have been operated on within the past three years, and the sixth was seen some 20 years ago while I was working in the residency training program.

CASE 1.—Miss K. R., aged 31, referred by Dr. Edward Massie to Barnes Hospital, presented a history of chronic diarrhea of three years' duration, the presence of blood and mucus in stools and, in recent months, a weight loss of some 15 pounds (6.8 Kg.). Several whole blood transfusions were required to correct the simple anemia. Proctosigmoidoscopic examination revealed several polyps, all small and benign in appearance and confirmed by microscopic study. Barium enema with air contrast revealed extensive polyposis of the colon.

In April 1947 an ileoproctostomy was performed and total colectomy carried out. Convalescence was uneventful; proctoscopy has been done at regular intervals, and 14 additional polyps have been fulgurated (figs. 3 and 4).

13. Lilienthal, H.: Hyperplastic Colitis: Extirpation of the Entire Colon, the Upper Portion of Sigmoid Flexure and 4 Inches of the Ileum, Am. Med. **1**:164-165, 1901.

14. Gardner, C.: Polyposis of Colon, Arch. Surg. **56**:75-78 (Jan.) 1948.

15. Ravitch, M. M., and Sabiston, D. C. Jr.: Anal Ileostomy with Preservation of Sphincter: Proposed Operation in Patients Requiring Total Colectomy for Benign Lesions, Surg., Gynec. & Obst. **84**:1095-1099, 1947.

16. Bartlett, R., and Peck, M.: Multiple Polyposis of Colon, Surg., Gynec. & Obst. **90**:547-551, 1950.

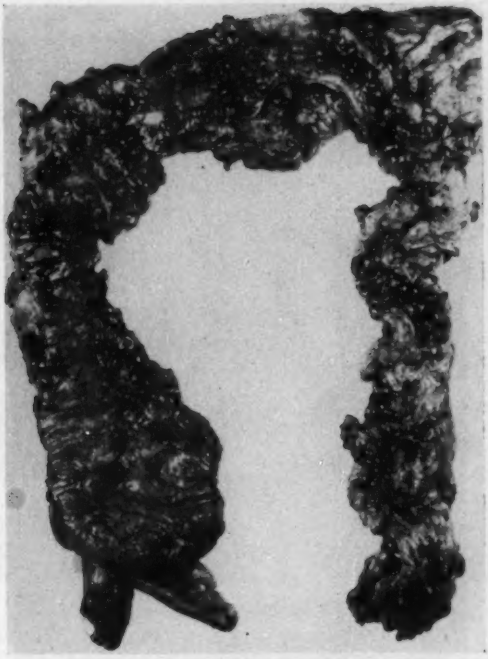

Fig. 3 (case 1).—The gross specimen.

Fig. 4 (case 1).—Postoperative roentgenogram after a contrast enema showing level of anastomosis.

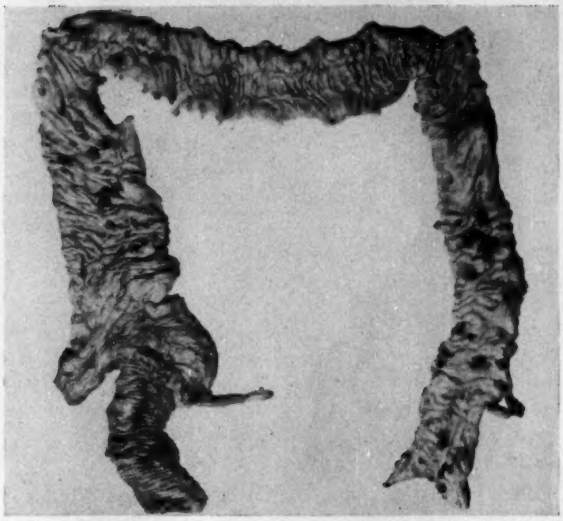

Fig. 5 (case 2).—Gross specimen.

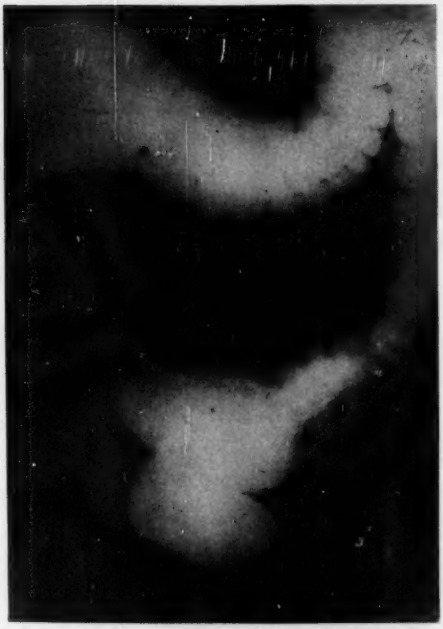

Fig. 6 (case 3).—Roentgenogram after barium enema showing cecal defect in 1930

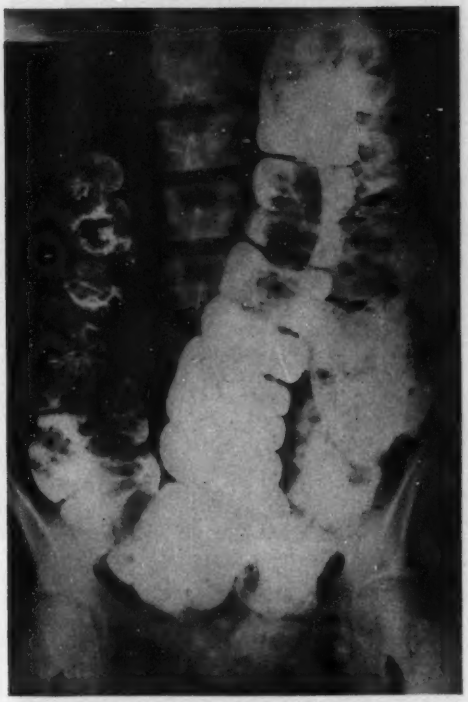

Fig. 7 (case 4).—The "marbleizing" effect seen after a contrast enema.

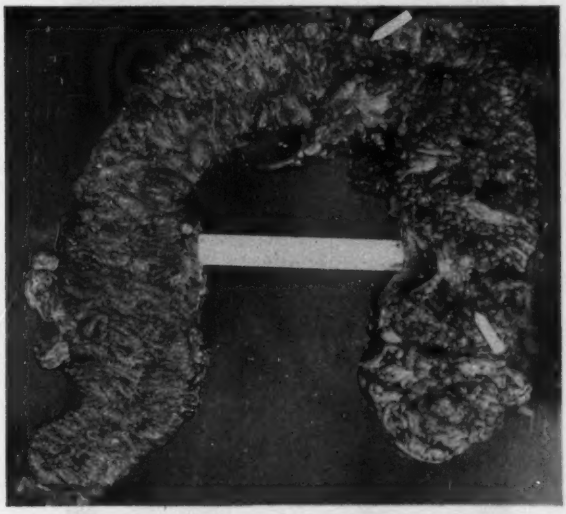

Fig. 8 (case 4).—Gross specimen showing malignant degeneration.

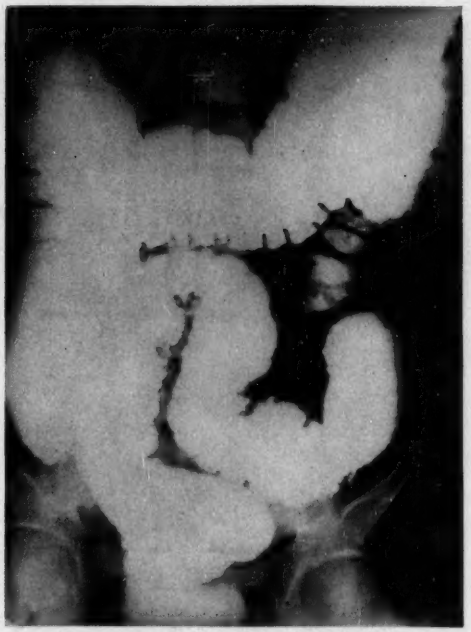

Fig. 9 (case 5).—Roentgenogram showing total loss of detail after ordinary barium enema.

Fig. 10 (case 5).—Contrast roentgenogram following evacuation of barium enema showing presence and extent of polyposis.

Fig. 11 (case 5).—Gross specimen.

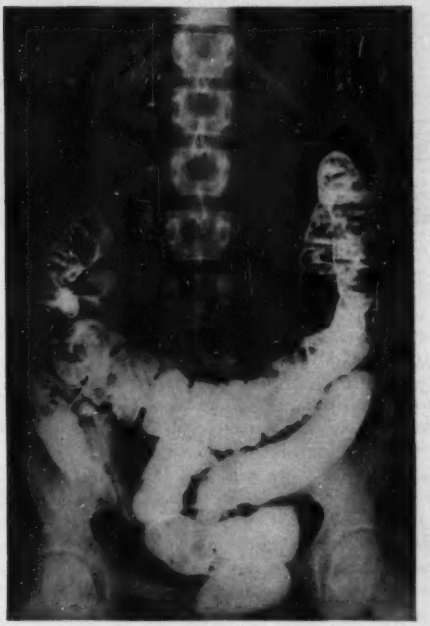

Fig. 12 (case 6).—Roentgenogram after a typical contrast barium enema.

CASE 2.—Wm. R., aged 25, brother of the first patient, was in the army at the time of his sister's operation but was reported by his mother to have had "bowel trouble" for a number of years. Hemorrhoidectomy had been performed while he was in the army. On his discharge he was admitted to Barnes Hospital. The classical history and the physical findings were confirmed by a barium enema and air contrast roentgenogram. In December 1948 an ileoproctostomy with total colectomy was performed. He has been observed at frequent intervals, but only two small polyps have been seen and fulgurated since the operation (fig. 5).

CASE 3.—G. W. R., aged 42, was the father of patients 1 and 2. When the mother was questioned as to the cause of his death, it was found that he too had had a typical history and had been admitted to Barnes Hospital with carcinomatosis arising in the large bowel. This external development followed an appendectomy performed six months prior to his admission. The wound never healed, and the patient died in his forty-third year, in 1930 (fig. 6).

Fig. 13 (case 6).—Gross specimen.

CASE 4.—Mrs. M. D., aged 43, referred by Dr. Louis F. Aitken to Barnes Hospital, presented a history of chronic diarrhea for three years with typical roentgenologic findings. Proctoscopic examination revealed malignant degeneration of polyps.

At operation in May 1949, the malignant degeneration was confirmed, with three separate areas, the rectum, sigmoid and splenic flexure, involved. The cecum was not involved, and an abdominoperineal resection was performed, all the colon except the cecum being removed. The patient has been followed up, and no further polyps have been found on examination of the stoma through the proctoscope (figs. 7 and 8).

CASE 5.—J. D., aged 25, son of the patient in case 4, was admitted to Barnes Hospital with a history of bowel irregularity, blood and mucus in the stools and weight loss of two years' duration. A barium enema and air contrast roentgenograms were pathognomonic of polyposis. Proctosigmoidoscopic examination showed polyps, but microscopic sections failed to reveal any malignant degeneration.

In November 1949, total colectomy with ileostomy was performed. There was gross evidence of carcinoma just above the peritoneal reflection so the rectum was removed as well. A Koenig-Rutzen bag has proved satisfactory, and he has not shown any clinical evidence of a recurrence (figs. 9, 10 and 11).

CASE 6.—Mrs. A. L., aged 27, sister of J. D. (case 5) and daughter of Mrs. M. D. (case 4), had bowel irregularity for three years, with considerable mucus but no blood. In November 1949, on the day after the brother's laparotomy, an ileoproctostomy with colectomy was performed. On the twelfth postoperative day it was necessary to perform a temporary ileostomy because of obstruction. The immediate convalescense was then uneventful, and the ileostomy stoma practically closed spontaneously, but acute intestinal obstruction developed suddenly, and a laparotomy was performed elsewhere. The patient is now in good health, without any evidence of new polyps or malignant development (figs. 12 and 13).

CONCLUSIONS

Familial polyposis of the colon is a specific clinical entity. The diagnosis and extent of the disease can be confirmed by means of contrast enemas.

The use of vitamin C, whole blood and nonabsorbable sulfonamides permits preparation of the patient for operation.

The present residency training program provides excellent technical assistance, and modern advancements in anesthesia permit one to carry out an extensive surgical procedure effectively, with minimal surgical risk to the patient.

The end to end anastomosis between the terminal portion of the ileum and the distal 3 cm. of the sigmoid over a rubber tube (as popularized by Dr. Balfour) reduces the number of suture lines to a minimum, provides adequate decompression proximal to the suture line, thus removing intraluminary tension, and accelerates the rate of wound healing by its "splinting effect," a mechanical factor. The anastomosis should be carried out prior to the surgical removal of the colon.

Although the major branches of the superior mesenteric artery must be ligated individually, the trunk of the inferior mesenteric artery can be ligated close to its aortic origin.

The one stage procedure permits maximum surgical treatment at the optimum time, and in our experience the remaining rectal segment can be thoroughly checked and other polyps destroyed by fulguration through a proctoscope.

DISCUSSION

DR. ROBERT W. BARTLETT, St. Louis: It is now generally agreed that if we are to avoid the almost certain development of carcinoma in multiple polyposis of the colon or hope to cure those patients in whom malignant degeneration is already present, some type of extensive resection of the large bowel will inevitably be necessary. I shall confine my remarks largely to a discussion of what appears to me to be the merits of the two principal modes of attack on the problem.

As you have just heard, Dr. Walton and many others favor fulguration of polyps in the rectum and rectosigmoid when possible in combination with total colectomy and ileorectal or low ileosigmoid anastomosis, with subsequent close observation of the retained rectal segment. This has the great advantage of preserving rectal sphincter function.

The second principal approach to the problem involves resection of the rectum and colon accompanied with the formation of a permanent ileostomy, and this view has many supporters, with good reason. Ravitch and Sabiston, after seeing a patient die of carcinoma in the retained rectal segment, make the apt comment that "the disease is preponderantly familial, and a genetic predisposition to polyp formation should be expected to persist in this mucosa, however often it is fulgurated, with malignant degeneration constantly threatening as long as the patient lives.

"In short, multiple polypoid adenomatosis of the colon is a symptomatically troublesome condition with dangerous malignant potentialities. The only safe treatment is permanent eradication of the abnormal epithelium. When the entire colon is involved this means total colectomy."

Certainly one must think twice as to the wisdom of doing an extensive resection only to leave behind the very segment in which cancer most often develops.

Hoxworth and Slaughter summarized a group of resections for polyposis reported in the American literature since 1930 and showed that in the group in which the rectal segment was preserved and fulgurated death from cancer of the rectum occurred in 25 per cent within one to six years. This would certainly seem another strong argument for including the rectum almost without exception in the resection.

The analysis of these authors is in accord with our own view that excellent results can be expected if an abdominoperineal resection is done as a first stage, followed in several weeks by colectomy and ileostomy at the second stage. The sequence of resections would be varied, of course, if there were evidence that a carcinoma was already present in a segment other than rectum or sigmoid.

The disagreeable features of the standard permanent ileostomy have long been a deterrent to resection of the rectum when it could possibly be avoided, but now with the availability of the split-thickness skin grafted ileostomy, as described by Dragstedt and employed subsequently by Sanders, myself and others with great satisfaction, one should have little hesitation in resecting the rectum if this increases greatly the patient's prospects of remaining permanently well.

PROGNOSIS OF GASTRIC CARCINOMA

Effect of Extent of Resection

WALTON D. THOMAS, M.D.

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AND

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IT IS POSSIBLE that total gastrectomy is the treatment of choice in all carcinomas of the stomach.[1] Because of the excessive gravity of this suggestion, its worth should be critically evaluated from every possible angle before it is generally adopted.

A mere philosophy of radicalism is not sufficient. The concept of removing the entire substance of any nonvital organ harboring cancer is not necessarily valid. This concept carried to the point of absurdity would suggest the removal of the entire face for a small basal cell carcinoma. A more valid, and probably more radical over-all concept, is that of removing all areas suggested by the known pathologic characteristics of a given malignant lesion.

Strict observance of the pathologic aspects of malignancy has seldom failed to bear surgical fruit. This is true regardless of whether it leads to a more conservative or a more radical operation. In any historical review of the surgical treatment of a malignant condition, one basic fact stands out: operations based on sound principles of pathology survive; those based on unsound principles of pathology die out. In the surgery of cancer, all problems of mortality, morbidity, and postoperative physiology ultimately yield to study, if an operation is justifiable pathologically.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

Dr. Thomas is a Fellow in Surgery, Mayo Foundation; Dr. Waugh is from the Division of Surgery, and Dr. Dockerty from the Division of Surgical Pathology, Mayo Clinic.

Abridgment of thesis submitted by Dr. Thomas to the Faculty of the Graduate School of the University of Minnesota in partial fulfilment of the requirements for the degree of Master of Science in Surgery.

1. (*a*) Ranson, H. K.: Total Gastrectomy, Arch. Surg. **55**:13-29 (July) 1947. (*b*) Longmire, W. P., Jr.: Total Gastrectomy for Carcinoma of the Stomach, Surg., Gynec. & Obst. **84**:21-30 (Jan.) 1947. (*c*) Lahey, F. H., and Marshall, S. F.: Should Total Gastrectomy Be Employed in Early Carcinoma of the Stomach? Experience with 139 Total Gastrectomies, Ann. Surg. **132**:540-560 (Sept.) 1950. (*d*) de Amesti, F.: Gastric Carcinoma, Surg., Gynec. & Obst. **91**:112-114 (July) 1950. (*e*) Allen, A. W., in discussion on Lahey and Marshall.[1e]

Thus, in the past ten years, the mortality of total gastrectomy has become acceptable,[2] and the morbidity has decreased tremendously. The problems of postoperative physiology are yielding rapidly, and further progress is to be expected.[3]

Pathologically, the operation has justified its worth for the large, extensive lesions which require it.[4] On the other hand, there is little published pathologic evidence supporting the advisability of total gastrectomy for small cancers of the stomach. The chief problems are those of intramural spread and of recurrence in the gastric stump.

No study has been found which showed a microscopic spread of more than 4 cm. beyond the gross spread of a gastric malignant lesion. Observations on intramural spread by Cunéo [5] and by Moynihan,[6] and later duplicated and confirmed by Verbrugghen [7] have stood unchallenged to the present time.

Similarly, despite a paucity of evidence, there is a widespread clinical impression that only a small percentage of gastric carcinomas recur in the gastric stump and that when this happens it is usually of secondary importance to other widespread recurrence. This impression has been strengthened recently by Allen.[1e]

On the other hand, this impression has been challenged by Warren,[8] who found 19.6 per cent of 122 patients dying from recurrent cancer to have the recurrence in the gastric stump. Likewise in Argentina, de Amesti [1d] showed that in 18 of 143 cases (100 traced) there was recurrence exclusively in the gastric stump. Verification in these cases was by both roentgenography and gastroscopy but not by necropsy.

Certainly these studies show again the overwhelming importance of proper pathologic examination of all excised specimens. Both the proximal and the distal edges should be examined microscopically, and if malignant changes are found or if duodenal involvement is present, more tissue should be removed. Whether or not total gastrectomy would have cured the patients in Warren's or de Amesti's series is problematic.

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2. (*a*) Smithwick, R. H.: Total Gastrectomy with Particular Reference to Closed (Aseptic) Esophagojejunostomy, New England J. Med. **237**:39-47 (July 10) 1947. (*b*) Scott, H. W., Jr., and Longmire, W. P., Jr.: Total Gastrectomy: Report of 63 Cases, Surgery **26**:488-498 (Sept.) 1949. (*c*) Waugh, J. M., and Fahlund, G. T. R.: Total Gastrectomy, S. Clin. North America **25**:903-917 (Aug.) 1945. (*d*) State, D.; Moore, G. E., and Wangensteen, O. H.: Carcinoma of the Stomach: A 10 Year Survey (1936 to 1945 Inclusive) of Early and Late Results of Surgical Treatment at the University of Minnesota Hospitals, J. A. M. A. **135**:262-267 (Oct. 4) 1947. Lahey and Marshall.[1e]

3. Weir, J. F.: Total Gastrectomy: Report of a Patient Surviving for 8 Years, S. Clin. North America **26**:934-940 (Aug.) 1946. Farris, J. M.; Ranson, H. K., and Coller, F. A.: Total Gastrectomy: Effects upon Nutrition and Hematopoiesis, Surgery **13**:823-833 (June) 1943. Lahey and Marshall.[1e] Scott and Longmire.[2b]

4. Pack, G. T., and McNeer, C.: End Results in Treatment of Cancer of Stomach: Analysis of 795 Cases, Surgery **24**:769-778 (Nov.) 1948. Lahey and Marshall.[1e] Smithwick.[2a] Waugh and Fahlund.[2c]

5. Cunéo, B.: L'envahissement du système lymphatique dans le cancer de l'estomac, Gaz. d. hóp. **73**:125-127, 1900.

6. Moynihan, B. G. A.: The Operative Treatment of Cancer of the Pyloric Portion of the Stomach, Tr. Clin. Soc. London **35**:20-26, 1901-1902.

7. Verbrugghen, A.: Intramural Extension of Gastric Carcinoma, Arch. Surg. **28**:566-579 (March) 1934.

8. Warren, S., cited by Lahey and Marshall.[1e]

In the one reported series wherein total gastrectomy was carried out on large and small cancers alike for a period of several years, the results were disappointing. Scott and Longmire [2b] reported that only 18 per cent of their patients were alive one or more years after operation. Their study was begun in 1944 and is continuing at the present time. These results were no better than those in several other series wherein the extent of resection was variable.[9]

Prior to the advocacy of total gastrectomy for all cancers of the stomach, the accepted treatment for a malignant growth in the distal two thirds of the stomach was radical subtotal gastrectomy.

A properly performed subtotal gastrectomy should remove the entire lesser curvature, including the gastrohepatic omentum. The left gastric artery should be ligated at the celiac axis, and the entire left gastric artery along with the coronary falx in which it runs forward to the stomach should be removed. The short gastric vessels should be ligated as close to the spleen as possible. The entire gastrocolic ligament should be removed. Two and one-half centimeters of duodenum should be removed where possible, particularly when the tumor abuts on the pylorus. The infrapyloric nodes must be removed completely in all cases regardless of the location of the tumor or the apparent involvement of these nodes. The spleen and the omentum below the colon may be removed if one feels that this is desirable.

This type of radical gastrectomy, only slightly modified, was first outlined by Cunéo [6] in France in 1900. It was reemphasized in 1907 by Jamieson and Dobson [10] in one of the clearest articles on the basic aspects of this subject in the English language.

Jamieson and Dobson [10] further emphasized a point which is of utmost importance then and now. They stated that no operation for cancer of the stomach is a truly radical one in the sense that all the tributary lymph channels and nodes, even of the primary type, are removed. Once the cancer has begun to invade lymph channels, a radical operation is achieved only by chance even though one is able to carry out the ideal procedure as dictated by the anatomy and physiology of the gastric lymphatic vessels. Their paper is an extraordinary mixture of excellent scientific investigation and common sense.

On the basis of the foregoing considerations and extensive reviews of the gastric lymphatic vessels by Cunéo,[6] Jamieson and Dobson,[10] Rouvière,[11] and many others, it is difficult to see what lymph nodes, if any, would be removed by total gastrectomy that could not be removed by a careful subtotal procedure, except for one or two juxtacardiac nodes of most limited pathologic importance and the nodes of the splenic hilus, which are likewise relatively unimportant pathologically unless the carcinoma involves the upper one third of the stomach. Furthermore, the spleen with its hilar nodes can easily be removed in subtotal resection if one feels that it is advisable.

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9. Lahey and Marshall.[1e] Allen.[1e] Waugh and Fahlund.[2e] Pack and McNeer.[4]

10. Jamieson, J. K., and Dobson, J. F.: Lectures on the Lymphatic System of the Caecum and Appendix, Lancet **1**:1061-1066 (April 20) 1907.

11. Rouvière, H.: Anatomy of the Human Lymphatic System, translated by M. J. Tobias, Ann Arbor, Mich., Edwards Brothers, Inc., 1938, 318 pp.

The problem in our investigation, however, was to see if this fact was borne out pathologically. It was realized that a definite study was impossible without the use of rigid control studies, with similar cancers treated by subtotal and by total gastrectomy. Nevertheless, it was decided to attempt a controlled pathologic study on lesions for which less extensive but variable degrees of resection were carried out.

PRESENT STUDY

All gastric cancers removed at the Mayo Clinic from 1920 to 1940, inclusive, were studied. From a large group, we were able to select 147 tumors similar in regard to size, location in the stomach, grade of malignancy and gross type. The typical lesion was a relatively localized cancer with ulceration of its surface and measuring 3 to 5 cm. in the greatest diameter. These conformed approximately to the Borrman classification, type II. All were located in the distal one third of the stomach, and all were microscopically graded 3 or 4 (Broders' method). As all specimens had been in fixative for at least seven years, no correction for shrinkage was made. These gross specimens were carefully measured and divided into groups based on narrow and wide resections, and then follow-up studies were carried out.

TABLE 1.—*Prognosis Based on the Extent of Resection Above and Below the Tumor*

	Extent of Resection Beyond Tumor			
	Less than 3 Cm. Above or Less than 2 Cm. Below or Both		3 Cm. or More Above and 2 Cm. or More Below	
	Cases	Per Cent	Cases	Per Cent
Total cases	120	..	27	..
5 year survivals	26	22	8	30
Cases with nodes involved	64	..	13	..
5 year survivals	6	9	3	23
Cases without nodes involved	56	..	14	..
5 year survivals	20	36	5	36

The dividing line between a narrow and a wide resection was more or less arbitrarily determined. The margin above the growth was 3 cm. or more in approximately one half of the cases studied and less than 3 cm. in approximately one half. The margin below the tumor was 2 cm. or more in approximately one half of the cases and less than 2 cm. in one half. These limits were then established as the criteria for a narrow or wide resection. It must be pointed out that all measurements were on specimens fixed for prolonged periods of time, and the measurements given are less than would be found in fresh, unfixed specimens. The error, however, is uniform and should not affect the study.

The relation of the extent of resection to prognosis was determined in a variety of ways to see if the methods would conflict. It was determined on the basis of a wide resection above and below, on the basis of the total length of the specimen, on the basis of the additive total of the margin above and below, on the basis of the margin above only and on the basis of the margin below. Each of these methods had some merit, but it was felt that the most valid method was that based on an adequate margin above and below the tumor (table 1). The results of the various methods were in surprising agreement.

When all the tumors were included, there was no difference in prognosis between the cases with narrow resections and those with wide resections.

If one considers only those cases with lymph nodes involved by cancer, there were two and one-half times as many five year cures resulting from wide resections as resulting from narrow resections. Despite the small numbers involved, this figure seemed significant.

For purposes of comparison, the results of the other methods of determining narrow or wide resections are included (tables 2, 3 and 4).

TABLE 2.—*Prognosis Based on Various Methods of Determining Extent of Resection: All Cases*

	Narrow Resection			Wide Resection		
		5 Year Survival			5 Year Survival	
Based on	Total Cases	Cases	Per Cent	Total Cases	Cases	Per Cent
1. Adequate margin above and below...	120	26	22	27	8	30
2. Total length of specimen.....	73	16	22	74	18	24
3. Total of margin above and below...	71	16	23	76	18	24
4. Free margin above.....	67	16	24	80	18	23
5. Free margin below.....	90	19	21	57	15	26

TABLE 3.—*Prognosis Based on Various Methods of Determining Extent of Resection: Cases in Which Lymph Nodes Were Involved*

	Narrow Resection			Wide Resection		
		5 Year Survival			5 Year Survival	
Based on	Total Cases	Cases	Per Cent	Total Cases	Cases	Per Cent
1. Adequate margin above and below...	64	6	9	13	3	23
2. Total length of specimen.....	32	1	3	45	8	18
3. Total of margin above and below...	33	2	6	44	7	16
4. Free margin above.....	29	2	7	48	7	15
5. Free margin below.....	46	4	9	31	5	16

TABLE 4.—*Prognosis Based on Various Methods of Determining Extent of Resection: Cases in Which Lymph Nodes Were not Involved*

	Narrow Resection			Wide Resection		
		5 Year Survival			5 Year Survival	
Based on	Total Cases	Cases	Per Cent	Total Cases	Cases	Per Cent
1. Adequate margin above and below...	56	20	36	14	5	36
2. Total length of specimen.....	41	15	37	29	10	34
3. Total of margin above and below...	38	14	37	32	11	34
4. Free margin above.....	38	15	40	32	10	31
5. Free margin below.....	44	15	34	26	10	38

COMMENT

The question of total gastrectomy for all gastric cancers is a provocative one. It should not be decided, however, on grounds of dissatisfaction with present modes of treatment. It must be decided on its merits pathologically and on its end results in terms of years of life. Years of enjoyable life must also be considered, but this can be a secondary consideration, since proper studies will solve postoperative problems as experience increases. The one series based on this concept at the present time has given most disappointing results.[2b]

The results of our study suggest that removal of the entire stomach is of little importance in the type of cancers chosen for the study. We do not feel that this concept is proved, because the small number of cures in any study of gastric cancer makes accurate statistical evaluation difficult. At the same time, this study definitely suggests that a wide careful dissection of the regions of lymph drainage is of distinct value and of great prognostic importance. Perhaps in the past there has been too much pessimism regarding the value of radical dissection of nodes in gastric cancer.

Two additional points should be emphasized. The first is that gastric cancer is not a homogeneous entity. The growths do not all look or behave alike. Since there are no presently acceptable classifications, investigators must closely define the gastric malignant tumors with which they are dealing. In reports of mortality, morbidity and survival, all benign conditions and sarcomas must be carefully separated. In addition, even in the group of carcinomas, the extent, the gross type, the microscopic type and the areas of spread must be closely defined.

Thus, our study has no bearing on the advisability of total gastrectomy for small infiltrative cancers of the so-called scirrhous type. Total gastrectomy might well be advisable for this group, as Warren [12] has suggested. Our study probably bears on only one definite type of small cancer. Fortunately this is a fairly common type. The chief value of the study is in interpreting this report in respect to the type of cancer studied.

The second point which should be emphasized is that total gastrectomy and a radical dissection of lymph nodes are not synonymous. One may do a total gastrectomy, removing the entire omentum, and still leave the most important nodes of all in the intrapyloric region and at the origin of the left gastric artery. Conversely, practically every node which can be removed in total gastrectomy can be removed in a thorough subtotal gastric resection, and this should be done routinely.

Finally, we wish to emphasize that the measurements used in this study are arbitrary and do not necessarily indicate an adequate removal of normal stomach above or below a gastric lesion. As a general rule the line of section of the stomach and duodenum above and below a carcinoma should be the maximum permissible under the circumstances.

SUMMARY AND CONCLUSIONS

One hundred and forty-seven cases of gastric cancer in which operation was performed at the Mayo Clinic from 1920 to 1940, inclusive, were selected for study. In these cases the lesions were (1) of grade 3 or 4 malignancy (Broders), (2) single, (3) located in the distal one third of the stomach and (4) from 3 to 5 cm. in greatest diameter. Including all cases, the prognosis in those in which resection was done 3 or more centimeters above the tumor and 2 or more centimeters below was not statistically better than in those with more limited resections. When only those cases with involved nodes were considered, the patients in whom wide resections were done had approximately two and one-half times as many five year cures as those in whom narrow resections were performed. Whether or not nodal involvement is suspected, a careful subtotal gastrectomy should be performed in all cases with thorough removal of every known area of lymphatic spread.

12. Warren, S., in Discussion, J. Nat. Cancer Inst. **7**:419 (April) 1947.

The question of total gastrectomy for all small lesions is not settled. The pathologic characteristics do not justify total gastrectomy in lesions of the type investigated herein. It is conceivable that total gastrectomy might be justified for even small cancers of the scirrhous or invasive types. An improperly performed total gastrectomy might actually remove less lymph node-bearing tissue than a properly performed subtotal gastrectomy.

DISCUSSION

DR. EDWIN M. MILLER, Chicago: Those of you who had the good fortune to be at the University Hospital on Wednesday afternoon and who listened to the papers by Dr. Lewis and Dr. Hubbard could not help but be impressed by the strenuous efforts that are being made to employ the most radical methods at our disposal in the eradication of cancer.

I think we all realize that as far as cancer of the stomach is concerned the lesions which develop in the silent areas remain symptomless much too long and therefore rarely come to operation while anything of permanent value can be accomplished. That is why this study by Drs. Thomas, Waugh and Dockerty is extremely valuable, because it focuses our attention on a group of patients all having the lesion in the same place, i. e., the pyloric antrum, where the chance of early symptoms could cause these patients to consult the surgeon in time to have something worth while undertaken.

There are certain pitfalls which lie in the path of the surgeon who is endeavoring to do his best in this field, and one of them is that it is not always an easy matter to decide on resectability as far as cure is concerned. As Dr. Thomas has so clearly shown, there is a free communication between all four main areas of distribution of lymph flow from the stomach and likewise a free intramural communication not only between the stomach and the esophagus but also between the pylorus and duodenum, and there is plenty of clinical evidence to show that the surgeon at operation may have considerable difficulty in deciding by the ordinary gross methods at his disposal, namely, palpation and inspection, whether or not the carcinoma has already gone beyond the normal borders of the stomach. In substantiation of this is the recent report of Max Zinninger and his associates in Cincinnati on a series of patients in whom the lesions were located within 2 inches of the pylorus. The pathologist was able to demonstrate in 25 per cent of these persons microscopic invasion of the duodenal wall by the tumor at a level considered perfectly normal by the surgeon. Likewise, it may be difficult to decide by gross methods whether or not the lymph nodes adjacent to the stomach have been invaded at the time of surgical intervention. This point was vividly brought out by Weinberg and his associates (California) after they injected Pontamine sk· blue dye at various places in the stomach wall before gastric resection was started.

There is also another pitfall, and this has to do with certain long-standing prejudices which must be overcome. One is that too many of our medical colleagues still cling tightly to the notion that chronic gastric ulcer is a medical problem and should be considered surgical only when there is definite evidence that a carcinoma exists. The other is that many persons believe that total gastrectomy is too formidable a procedure from a technical point of view, that it is accompanied with too great a mortality risk and that patients who have been deprived of their stomachs are necessarily permanently unhappy and are in a hopeless condition. There are men in this audience this morning whose work has furnished proof to the contrary, and I refer in particular to Drs. Walters, Gray, Priestley, Waugh and Judd, of the Mayo Clinic, where between 1940 and 1948 the incidence of total gastrectomy was more than six times that of the previous decade, with an ever decreasing mortality to approximately 7 per cent; to Dr. William Longmire, of California, who in a recent publication cited a series of 20 patients on whom he had performed total gastrectomies while still in Baltimore, with loss of only two, and also to Dr. Wangensteen, who, in addition to having made significant contributions to the technique of this operation, has recently reported a group of 28 patients with the amazingly low mortality rate of 3.5 per cent.

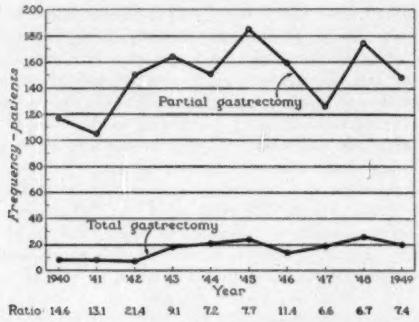
I think we are faced in a practical way with this question: If you or I had an early carcinoma of the stomach located in the pyloric region, which appeared grossly to be resectable from the standpoint of cure, how much of a resection would we like to have done on ourselves?

Recently I put that question to three of my colleagues in Chicago. One of them was our chief pathologist at the Presbyterian Hospital, Dr. George Hass, and another was chief of the medical department, Dr. Howard Armstrong. Both of these men without hesitation replied: "Total gastrectomy!" The third, Dr. Francis Straus, one of our best surgeons, after thinking a moment, said: "I would like to have as radical an operation as is possible, consistent with safety, including removal of the entire great omentum and the spleen and ligation of the left gastric artery close to the celiac axis, so that all available lymph nodes could be removed, but I would prefer that the surgeon leave a small portion of the fundus of the stomach intact, so that the anastomosis could be made between it and the jejunum."

Which of those answers is the correct one? I am not sure. Time will tell, and the answer awaits a careful comparative study of parallel series of cases, as carefully studied and followed up as the group of cases which the authors of this paper have presented.

Dr. Edward E. Mason, Minneapolis: Dr. Barkley, Dr. Kelly and I have recently reviewed the cases of carcinoma of the stomach at our hospital, and during 1943 and 1944 the five year survival rate was 15.8 per cent.

In analyzing the data further to determine if this rate represented a true improvement in the surgical treatment or if part of it could be attributed to other factors, we found that during this period 66 per cent of the patients who underwent partial gastrectomies had negative lymph nodes. During this period the five year survival for cases with positive lymph nodes was 14 per cent, whereas in the negative group it was 50 per cent.



Malignant lesions of the stomach.

The information obtained from studies such as we have heard about this morning is a type that I am sure we need before we can feel justified in increasing the extent of the operation.

In trying to find out more about what we can do, Dr. Wangensteen is asking that the spleen and the greater omentum be removed routinely en bloc during the dissection. These specimens are being studied by the clearing technique. Also, we may obtain some information by a study of the cases that are being explored a second time. In cases in which recurrences are found, we will learn, before symptoms occur, just where those recurrences are.

Dr. John M. Waugh, Rochester, Minn.: I should like to emphasize that we still do a few total gastrectomies, because we do feel that total gastrectomy is indicated for certain lesions. Any lesion which cannot be removed radically by means of a subtotal operation should be removed by means of a total operation if there is no distant spread, and the mortality rate of total gastrectomy has now reached such a point that one could consider doing it as a palliative procedure, which we have not done in the past.

The accompanying graph of the incidence of total gastrectomy as compared to subtotal operations performed from 1940 through 1949 shows that the number of total gastrectomies performed has leveled off to an average of about 20 to 25 a year since 1943.

As far as our practice is concerned, unless patients reach us earlier than they have in the past, I see no way by which this figure can go any higher unless we do palliative operations.

That, of course, will not increase the five year rate of cure appreciably, but if some method of detecting gastric carcinomas earlier is provided, then certainly there will be a greater reason for total gastrectomy than there has been in the past.

With the lower mortality rate, undoubtedly certain patients who were poor risks and were not permitted to undergo total gastrectomy can be subjected to that operation in the future. Where this figure will level off, we do not know. Dr. Pack finds total gastrectomy indicated in 36 per cent of his resections done for gastric malignant disease.

Many years ago, at a meeting of this association, Dr. William Mayo emphasized that before carcinoma of the stomach could be diagnosed in its early stages exploration would have to be carried out in a certain number of patients with negative results of examinations. I think that our medical confreres, and sometimes we ourselves, forget that in certain instances the roentgenologist is handicapped, especially when lesions occur in the upper portion of the stomach. For a patient with a definite history of gastric carcinoma, I consider exploration to be indicated even in the face of roentgenograms which do not show evidence of lesions and gastroscopic examinations with negative results.

I should like to present such a case. A man from Montana was thought, from evidence shown on a roentgenogram taken at home, to have a lesion of the upper part of the stomach, but two subsequent roentgenograms taken at the same place did not confirm this diagnosis. However, the patient had definite symptoms. He did not have any free acids; results of two roentgenograms and a gastroscopic examination taken at the Mayo Clinic were negative. I felt that an exploration should be done. At operation I could feel a tiny plaque on the lesser curvature just below the esophagus. It did not feel like an ulcer. There was no crater.

I felt that this was one of the earliest scirrhous cancers that I had ever had in my hand. I am sure my assistants thought I must be insane to perform total gastrectomy, and I am sure Dr. Dockerty thought so when he saw the specimen in the laboratory, because grossly it looked perfectly normal. But when several sections of this plaque were taken, it was found to be an early scirrhous carcinoma. The operation was done about 18 months ago, so it is too soon to know what benefit this patient will obtain.

CONGENITAL INTRINSIC OBSTRUCTION OF THE STOMACH AND DUODENUM IN THE NEWBORN

CLIFFORD D. BENSON, M.D.
AND
JOHN J. COURY, M.D.
DETROIT

NOTABLE advances have been made in the reduction of mortality in acute intestinal obstruction in adults during the past 15 years, but comparable reduction has not been achieved for intestinal obstruction in the newborn. There are a number of reasons why this reduction has not been accomplished. In the latter group we are dealing with such factors as prematurity, associated anomalies or conditions and the fact that most of the obstructions encountered are of the complete type which produce marked changes in the physiological balance of the patients. When one considers that about one half of all deaths which occur during the first two weeks after birth are attributable to prematurity, one can understand the importance of this factor in a consideration of newborn infants as operative risks.

It has been estimated by Thorndike [1] that complete duodenal obstruction occurs in 1 in 30,000 births. In a review of 400 infants admitted to the Children's Hospital of Michigan with a diagnosis of intestinal obstruction over a seven year period, Evans [2] found that 16 per cent had atresias of some part of the gastrointestinal tract and 2 per cent had obstructions located in the duodenum. Intrinsic obstruction of the duodenum occurs in the second to third months of fetal life, at which time the intestine changes from a solid cord to the final form with a lumen lined with well defined epithelium. Failure of this process to develop in a normal manner results in atresia, stenosis or a diaphragmatic obstruction. These obstructions are practically always single in the stomach and duodenum, and it has been stated that stenotic lesions are never multiple. Calder in 1733 described the first case of duodenal occlusion found at autopsy. Ernst [3] in 1916 reported the first successful operation for complete intrinsic duodenal obstruction. O'Neill and others,[4] in a review of the literature in 1948, found 13 instances of recovery from complete duodenal atresia and 12 instances of recovery from probable duodenal atresia, but

From the Surgical Services of Harper Hospital and the Children's Hospital of Michigan.

1. Thorndike, A.: Duodenal Atresia and Stenosis in Infancy, Boston M. & S. J. **196**:763, 1927.

2. Evans, W. A., Jr.: Obstructions of the Alimentary Tract in Infancy, Radiology **51**:23, 1948.

3. Ernst, cited by Wagensteen, O. H.: Intestinal Obstructions, Springfield, Ill., Charles C Thomas, Publisher, 1947.

4. O'Neill, J. F.; Anderson, K.; Bradshaw, H. H.; Lawson, R. B., and Hightower, F.: Congenital Atresia of the Small Intestine in the Newborn, Am. J. Dis. Child. **75**:214, 1948.

there was no certainty as to the completeness of the occlusion. A further review of the subsequent literature [5] reveals an additional 31 successfully treated complete duodenal atresias and 11 successfully treated instances of incomplete obstruction or stenoses. This brings the total number of successfully treated infants with duodenal atresia and stenosis to 57.

It is difficult to ascertain the exact mortality rate in intrinsic obstruction of the duodenum in the newborn because few large series have been reported. The great majority of reports have dealt with single cases in which successful treatment has been given. The mortality in the few larger series until recent years has varied from 38 to 60 per cent. Recently, Duckett [5f] reported five duodenal atresias successfully treated, and Grove and Rasmussen [6] reported 11 patients with duodenal atresia and stenoses. Four of these patients were considered to be in such poor condition that surgical intervention was not believed to be indicated. All four died. Among the remaining seven patients operated on, there was only one death, an operative mortality of 14.3 per cent and an over-all mortality of 45.4 per cent. In this report, we are reviewing our experience during the past four years with one patient with intrinsic obstruction of the stomach and 10 patients with intrinsic obstruction of the duodenum.

INTRINSIC OBSTRUCTION OF THE STOMACH

A review of the literature reveals that only one previous newborn infant has been operated on successfully for intrinsic obstruction of the stomach. This patient was reported by Touroff [7] in 1940; a prepyloric membranous obstruction completely occluding the stomach was treated by multiple incisions and pyloroplasty, and the infant made a successful recovery. In this discussion we should like to add a second case of intrinsic obstruction of the stomach due to a diaphragm in the prepyloric area which completely occluded the pyloric outlet of the stomach.

B. I., a 4 day old female infant weighing 6 pounds (2.7 Kg.), was delivered of a hydramniotic mother and at the time of delivery swallowed considerable amounts of amniotic fluid and was distended. The infant vomited all feedings after birth, and there was a weight loss of 1 pound (0.5 Kg.). Examination of the patient on admission showed moderate dehydration and distention of the abdomen, with tympanites in the upper region. The vomitus contained only water and mucus. A flat plate roentgenogram showed a dilated stomach, with the distribution of gas limited to the gastric region and none visible in the duodenum or the remaining small bowel (fig. 1). This patient received preoperative intravenous injections of dextrose and water and was operated on on the sixth day of life. Laparotomy revealed that the entire duodenum and the remaining

5. (*a*) Ladd, W. E., and Lanmann, T. H., in Chistopher, F.: Textbook of Surgery, ed. 5, Philadelphia, W. B. Saunders Company, 1950, chap. 27, p. 1013. (*b*) Glover, D. M., and Barry, F. McA.: Intestinal Obstruction in the Newborn, Ann. Surg. **130**:480, 1949. (*c*) Lanmann, T. H., in discussion on Glover and Barry.[5b] (*d*) Kaplan, L.: Congenital Duodenal Obstruction Due to Atresia, Am. J. Surg. **79**:452, 1950. (*e*) Madding, G. F.; Everhart, M. W., and Heath, J.: Congenital Duodenal Atresia with Malrotation of the Intestine, Ann. Surg. **131**:433, 1950. (*f*) Duckett, J. W., in discussion on Grove and Rasmussen: Ann. Surg. **131**:869, 1950. (*g*) Benson, C. D., and Penberthy, G. C.: Congenital Duodenal Obstruction (Intrinsic Obstruction), Arch. Surg. **56**:58 (Jan.) 1948. (*h*) O'Neil and others.[4] (*i*) Leech, C. H., and Pinkerton, A. W.: Congenital Duodenal Atresia: Report of a Successful Surgical Case, J. Pediat. **33**:770, 1948.

6. Grove, L., and Rasmussen, E.: Congenital Atresia of the Small Intestine, Ann. Surg. **131**:869, 1950.

7. Touroff, A. S. W., and Sussman, R. M.: Congenital Prepyloric Membranous Obstruction in a Premature Infant, Surgery **8**:739, 1940.

portion of the gastrointestinal tract contained no gas and were collapsed. A gastrotomy was performed, and a diaphragm about one eighth of an inch (0.32 cm.) in thickness at the prepyloric area was excised and the raw surfaces sutured with interrupted silk sutures for hemostasis. Postoperatively the patient failed to retain feedings satisfactorily, and it was felt that there was considerable edema at the pyloric outlet of the stomach due to operative intervention. This diagnosis was confirmed at exploration one week after the resection of the prepyloric diaphragm. However, the patient continued to lose weight and to regurgitate a considerable portion of her

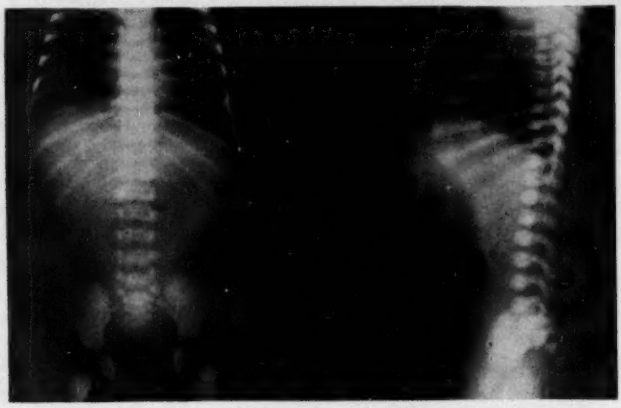


Fig. 1.—Anteroposterior and lateral roentgenograms showing gaseous distention limited to the stomach, indicating complete pyloric obstruction.

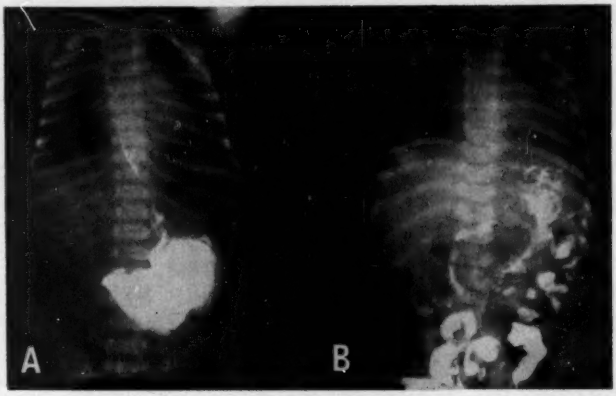


Fig. 2.—*A*, roentgenogram showing gastric retention at three hour interval. *B*, one taken after barium meal two months postoperatively. Barium passed entirely through the pylorus, and none passed through the gastroenterostomy stoma.

feedings, and it was felt that because of the partial obstruction at the site of the former diaphragm she would not survive unless a side-tracking procedure was accomplished (fig. 2*A*). An anterior gastroenterostomy was performed on the twenty-seventh day of life. After this procedure the patient improved rapidly. Check-up examination with a small amount of barium sulfate showed that the new gastroenterostomy was functioning satisfactorily, and the patient continued to gain weight. She was discharged from the hospital when 6 weeks of age. Two months post-

operatively another gastrointestinal study was done, which revealed that the barium sulfate passed entirely through the pylorus and none through the gastroenterostomy opening (fig. 2*B*). The patient was last seen at the age of 14 months and weighed 25 pounds (11.3 Kg.). She was taking all feedings and developing normally.

INTRINSIC OBSTRUCTION OF THE DUODENUM

Complete intrinsic duodenal obstruction is commoner than stenotic lesions. Over two thirds of obstructions are in the third portion of the duodenum. If the obstruction is above the bile ducts, the vomitus will contain no bile; if it is below the bile ducts the patient will have bile in the vomitus and, as is characteristic of all high obstructions in the intestinal tract, vomiting is an early symptom within the first 24 to 36 hours after birth and is the main one. Associated with this symptom in duodenal obstruction of high degree are peristaltic waves going from the left upper quadrant across the upper part of the abdomen to the right lower quadrant, and upper abdominal distention. In complete obstruction the flat plate of the abdomen shows that the gas is limited to the stomach and the duodenum, with none passing beyond the point of obstruction. We have not used barium sulfate mixtures to locate the site of complete obstructions because the gas pattern is usually sufficient in our experience. On the other hand, in cases of stenotic lesion with only an incomplete obstruction indicated by the fact that there is gas not only in the stomach and duodenum but also in the small bowel and colon, one can safely give a thin mixture of barium sulfate to identify the site of stenosis. In such cases the symptoms are those of partial obstruction. Many of the infants will not be seen for days or weeks later because they are treated for feeding problems and a true diagnosis is not made until barium studies are done. In a previous communication [5g] we described one infant who lived for 21 months before a gastrointestinal study was made and the true diagnosis discovered. This child responded well to duodenojejunostomy.

In this discussion we are presenting 10 patients with intrinsic obstruction of the duodenum. The case reports are as follows:

CASE 1.—G. S., a 2 day old premature infant girl weighing 4 pounds 3 ounces (1.9 Kg.), was admitted to the hospital with a history of vomiting of bile-stained fluid since the day of birth. Examination revealed the presence of peristaltic waves in the left upper quadrant going across the abdomen to the right. A flat plate roentgenogram of the abdomen showed gaseous distention of the stomach and duodenum, with no gas in the small bowel. The patient was admitted in a state of alkalosis, which was corrected by intravenous therapy. At operation the same day a moderately distended stomach and duodenum was found, and the obstruction was in the third portion of the duodenum. An antecolic duodenojejunostomy was performed. The Levin tube was removed 48 hours after operation, and the patient was given small dextrose and water feedings, which she retained. A flat plate of the abdomen taken on the second day postoperatively revealed gas throughout the small and large bowel indicating that the anastomosis was functioning properly. The weight of the baby at the time of operation was 4 pounds 3 ounces (1.8 Kg.), and she was one month premature. She had an uneventful postoperative course and was discharged on the eighteenth day after operation.

CASE 2.—J. R., a 3 day old male infant weighing 5 pounds 10 ounces (2.6 Kg.) was admitted to the hospital with a history of vomiting all feedings since birth. The vomitus contained bile. The upper part of the abdomen was distended and tympanitic while the lower region was flat and soft. The patient was slightly icteric. Roentgen ray examination of the abdomen (fig. 3*A*) on his admission revealed gas distention of the stomach and duodenum but no gas in the small bowel distal to Treitz's ligament. Laparotomy revealed a complete atresia at the duodenojejunal junction. A duodenojejunostomy was performed and intranasal gastric suction continued. The

Levin tube was removed at the end of 48 hours and glucose water feedings were instituted, but vomiting recurred and was bile stained. Because of the vomiting, a small amount of iodized oil U. S. P. (lipiodol, 40 per cent iodine) was then placed in the stomach and a flat plate taken, which showed (fig. 4*A*) retention of the greater portion of the oil in the stomach, with

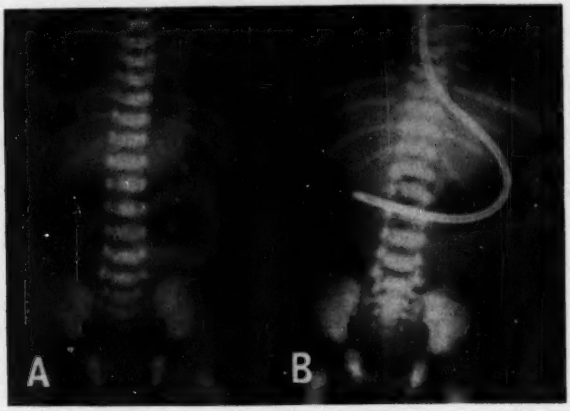


Fig. 3.—*A*, roentgenogram showing gaseous distention of stomach and duodenum and none of the remaining small or large bowel. *B*, shows decompression after Wangensteen suction applied preoperatively.

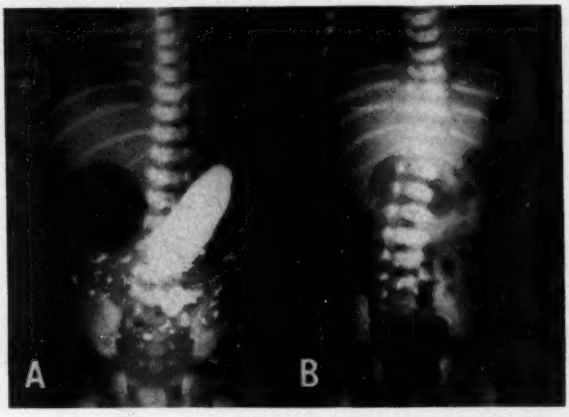


Fig. 4.—*A*, roentgenogram taken three days after duodenojejunostomy for atresia at duodenojejunal junction. Iodized oil has passed through anastomosis into small intestine in five hours. Note distention of first part of duodenum, indicating a second duodenal obstruction. *B*, roentgenogram of abdomen taken four days after removal of diaphragmatic leaflet in second portion of duodenum shows normal gas distribution of intestinal tract.

distention of the first and second portions of the duodenum, and a trickle of iodized oil which had escaped through the anastomosis into the small bowel. From this finding, it was felt that the patient had another obstruction in the duodenum, probably above the anastomosis. On the eighth day of life the laparotomy wound was opened. The former duodenojejunostomy stoma appeared

adequate, and the duodenum was opened above the anastomosis and a second obstruction consisting of a diaphragmatic leaflet was completely removed and the duodenum closed in two layers. The patient's convalescence was satisfactory. The Levin tube was removed at the end of 48 hours. The baby retained his feedings, and his postoperative course was uneventful (fig. 4 *B*). One month postoperatively his weight was 9 pounds (4.1 Kg.), and he was taking feedings with no further vomiting. He has remained well to this time, 25 months after operation.

CASE 3.—P. H., a 5 day old male infant weighing 5 pounds (2.3 Kg.), was admitted to the hospital with a history of vomiting all feedings since birth. The vomitus had been bile stained, and he had been jaundiced since the second day of life. The patient was a Mongolian newborn infant who had associated webbing of the fourth and fifth toes. The roentgen examination of the abdomen revealed gas distention of the stomach and the first and second portions of the duodenum and no gas in the small bowel (fig. 5 *A*). Operation was performed on the fifth day of life, and a complete obstruction of the third portion of the duodenum was found. A duodenojejunostomy was performed. Roentgen examination on the second postoperative day revealed gas in the small and large bowels (fig. 5 *B*). The patient's postoperative course was uneventful, and he was discharged on the fourteenth postoperative day. He has remained asymptomatic and is now 18 months of age.

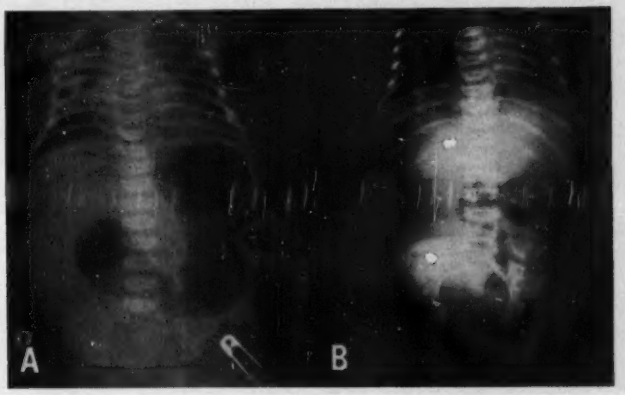


Fig. 5.—*A*, gaseous distention of stomach and duodenum indicating complete obstruction of duodenum. *B*, two days after duodenojejunostomy there is gas in small and large bowel.

CASE 4.—S. H., a 3 day old white female premature infant weighing 2 pounds 15 ounces (1.2 Kg.), was admitted to the hospital with a history of being two months premature. She had continued to vomit all feedings since birth, and the vomitus was bile stained. Examination revealed an emaciated and jaundiced premature infant with distention of the upper part of the abdomen and a severe degree of dehydration. A roentgenologic examination revealed gas distention of the stomach and the first two portions of the duodenum. Laparotomy revealed total obstruction in the third portion of the duodenum. A duodenojejunostomy was performed. Nasal gastric suction was continued for 48 hours, and on the second postoperative day the patient had two meconium stools. She retained the glucose water feedings, and at the end of the first postoperative week she weighed 3 pounds 2 ounces (1.4 Kg.). At this time the jaundice increased markedly. She began having liquid stools, and there was evidence that she was not digesting her milk formula. She was given proteolytic feedings. The feedings were tolerated, and the hemoglobin and serum proteins returned to normal. The infant continued to improve slowly, and she gained weight to 3 pounds 7 ounces (1.5 Kg.) and was taking her feedings well. On the twenty-seventh postoperative day she had continued to retain feedings and weighed 4 pounds (1.8 Kg.). At this time she vomited and became distended and diarrhea developed. Oral feedings were stopped, and continuous intravenous feedings were instituted. The blood chemistry and

nitrogen balance were maintained at normal levels. Despite all treatment, the patient gradually became worse, and she died on the twenty-ninth postoperative day. Postmortem examination revealed severe acute hepatitis and a good functioning duodenojejunostomy, with a complete diaphragmatic occlusion of the third portion of the duodenum.

CASE 5.—P. J., a 6 day old white female infant weighing 5 pounds 12 ounces (2.7 Kg.), was admitted to the hospital with the history of having bile-stained vomitus and small waxy stools. Physical examination revealed a jaundiced, dehydrated infant with a slightly distended abdomen. A gastrointestinal study with a small amount of liquid barium sulfate revealed an obstruction at the third portion of the duodenum and some gas in the distal small intestine (fig. 6*B*). Exploration on the day of admission revealed a stenosis of the third portion of the duodenum. A duodenojejunostomy was performed. The patient's postoperative course was uneventful, she was discharged on the twenty-first postoperative day and now, at 38 months, is developing normally.

CASE 6.—B. W., a 2 pound 10 ounce (1.2 Kg.), 2 day old female infant, was admitted to the hospital with the diagnosis of prematurity. On the third day of life she began regurgitating and became distended. The Farber test gave a negative reaction. X-ray examination of the

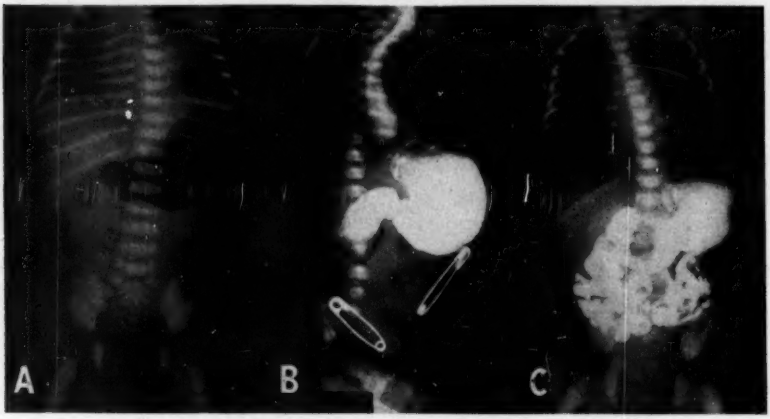


Fig. 6.—*A*, gas in the stomach and colon. *B*, barium meal demonstrating obstruction in third portion of duodenum. *C*, barium meal study 11 days after duodenojejunostomy showing satisfactory passage of barium sulfate into small bowel.

abdomen revealed gastric and duodenal dilatation, with no air beyond the duodenum. The patient had had no stools since birth. On the fifth day of life laparotomy revealed a complete atresia of the third portion of the duodenum, the duodenum ending in a blind pouch. There was a short mesenteric stalk with an associated 360 degree clockwise volvulus of the midgut. The volvulus was corrected, and a duodenojejunostomy was performed. The patient's course was uneventful until the seventh postoperative day, when she began regurgitating her feedings. A roentgenogram of the abdomen at that time revealed signs of small bowel obstruction. On the ninth postoperative day the patient was again taken to the operating room, and a mechanical obstruction just distal to the anastomosis was found. The adhesive bands were released. The patient's postoperative course was not satisfactory, and she died on the twelfth postoperative day. Postmortem examination revealed atelectasis, Bacillus coli bacteremia, acute cholecystitis and cholangitis, anomalous mesentery, incomplete rotation of the large bowel and a patent anastomosis.

CASE 7.—A. S., a 4 pound 3 ounce (1.9 Kg.), 2 day old white female infant, entered the hospital with the history of vomiting all feedings since birth. Physical examination revealed no abnormalities except for prematurity. The Farber test elicited a negative reaction. X-ray examination of the abdomen revealed a distended stomach and duodenum, with no air beyond

the duodenum. The patient was operated on the day of admission, and a duodenojejunostomy was performed for a complete obstruction in the third portion of the duodenum. She had an excellent postoperative course and was discharged on the seventh postoperative day.

CASE 8.—J. R., a 3 day old, 8 pound (3.6 Kg.) white female infant, was admitted to the hospital with the history of vomiting all feedings since the second day of life. The vomitus contained bile. Roentgenograms of the abdomen revealed a dilated stomach and duodenum, with no evidence of air beyond the duodenum. The patient was operated on on the fourth day of life, and a complete obstruction in the third portion of the duodenum was found. A duodenojejunostomy was performed. She had an uneventful course and was discharged on the fourteenth postoperative day and has remained well to the present time, 11 weeks postoperatively.

CASE 9.—E. O., an 8 day old, 3 pound 10 ounce (1.6 Kg.) white female infant, was admitted to the hospital with the history of being the first-born of a polyhydramnios mother. The infant had had no stools since birth and had been vomiting practically all feedings. Physical examination revealed a markedly jaundiced, dehydrated and weak premature infant. The upper part of the abdomen was distended, and gastric waves were visible. Roentgenograms of the abdomen revealed a distended stomach and duodenum. On the ninth day of life the patient was operated on, and a complete obstruction of the third portion of the duodenum was found. A duodenojejunostomy was performed. Postoperatively the patient's course was not completely satisfactory. Although her gastrointestinal tract functioned normally, she gained weight slowly and would become cyanotic when oxygen was withheld. Further examination revealed a congenital heart lesion (septal defect?). Seven weeks postoperatively she weighed 5 pounds 11 ounces (2.6 Kg.) and was out of the incubator at longer intervals.

CASE 10.—B. O., a 6 day old, 5 pound 1 ounce (2.3 Kg.) male infant, was admitted to the hospital with a history of vomiting since birth. The vomitus contained no bile. The abdomen was soft and was not distended. Roentgen examination showed complete obstruction in the second portion of the duodenum. Dehydration was corrected, and at operation two distinct dense bands were found passing from the liver to the stomach which were divided. The duodenum ended as a blind pouch just above the bile duct entrance. At this time the patient's general condition became poor, and it was not possible to do an anastomosis. The operative wound was closed, and on the eighth day of life the wound was reopened and an anterior gastroenterostomy was performed. On the fourth postoperative day there was bile drainage from the wound, indicating a breakdown in the anastomosis, and the patient died on the eighth postoperative day. Postmortem studies showed a "complete atresia ending just above the ampulla of Vater, necrosis at the anterior suture line with complete absorption of the catgut suture used in the Connell procedure and local peritonitis."

PREOPERATIVE, OPERATIVE AND POSTOPERATIVE MANAGEMENT

It is our belief that adequate preoperative preparation is paramount in the group of patients under discussion. This objective is obtained only by the close cooperation of the surgeon, pediatrician and anesthesiologist. The history and the physical examination are supplemented by roentgenographic study of the abdomen. We do not use barium sulfate in cases of complete obstruction for determining the site of obstruction because we believe that the gas pattern is usually sufficient. Immediately after the primary diagnostic procedures, nasogastric suction is instituted and chemical examination of the blood is made.

These patients are dehydrated and may have either alkalosis or acidosis, depending on whether or not gastric or duodenal contents have been lost in the vomitus. They may also have a depletion of their total proteins. The pediatrician, in cooperation with the surgeon, directs the fluid and electrolyte requirements in our patients. The intravenous feedings are calculated on the basic requirements of 60 to 90 cc. per pound per day for a newborn infant. This may vary, depending on the state of hydration and the maturity of the patient. The fluids consist of a mixture of one third or one half of saline and the remainder of 10 per cent dextrose in water.

Plasma (10 cc. per pound) or, for hypoproteinemia and anemia, whole blood (10 cc. per pound) is substituted for part of the saline to be given. If the patient's carbon dioxide level is 20 to 25 milliequivalents or less, the intravenous administration of fluids is maintained. If the carbon dioxide is 25 milliequivalents or greater, one-sixth molar ammonium chloride is given subcutaneously in the amount necessary to return the level to normal. If the alkalosis is so severe that apnea and tetany are present, 10 per cent carbon dioxide with oxygen is given and supplemented with intravenous administration of 10 per cent calcium gluconate. These are given as an emergency measure until the effects of the fluids given parenterally have been obtained. Synkamin® (vitamin K preparation) and vitamins B and C are given parenterally prior to surgical intervention.

Well trained anesthesiologists have been an important factor in the management of this group of patients. The anesthetic of choice has been drop ether. Shock has been largely eliminated by the judicious use of blood transfusion during the operative procedure and by accomplishing the surgical correction of the lesion in a reasonable length of time, gentle and meticulous handling of tissues and good hemostasis. In accomplishing the anastomosis for obstruction in the third portion of the duodenum, we have preferred an antecolic duodenojejunostomy. Two rows of 0000 sutures posteriorly and one or two rows anteriorly have been used depending on the size of the jejunum, except in a few instances in which we have used 0000 chromic surgical gut for the mucosal layer and the anterior Connell sutures. At the present time, we feel that 0000 silk is preferable for the entire anastomosis.

Postoperatively, nasogastric suction is continued for 36 to 60 hours. The patient's fluid balance is regulated as long as nasogastric suction is continued. The initial feedings consist of 2 to 3 drachms (8 to 12 cc.) of glucose water, offered at intervals of one to two hours. If the patient accepts and retains the feedings, supplementary fluids are given parenterally. If a patient has retained six to eight of these feedings and shows no signs of distress, a formula is instituted. Through trial and error we have found that the most satisfactory method of increasing the formula in the full term infant is by using the "pyloric regimen" but increasing the formula at "half speed." Premature infants are placed on the usual "premature stock formula."

Immediately after operation all premature infants are placed in incubators for the prime purpose of combating subnormal temperature. Oxygen is given to premature infants and to others if it is deemed necessary. Chemotherapeutic agents, chiefly penicillin, streptomycin and sulfadiazine, are given for the first four postoperative days, and their use is then discontinued unless there is some specific reason for giving them.

COMMENT

In a review of this series of patients with congenital intrinsic obstruction of the stomach and duodenum, certain factors stand out as playing a major role in determining the morbidity and mortality rates. Prematurity was exhibited by seven of the 11 patients operated on. For the classification of prematurity we have used the standard of any infant whose birth weight is less than 2,500 Gm. Of the three deaths in this entire series, two involved infants weighing less than 3 pounds (1.3 Kg.). One did well immediately after operation but died 29 days later of intercurrent hepatitis and severe diarrhea, and the other succumbed to Bacillus coli

bacteremia, atelectasis and acute cholecystitis and cholangitis four days after correction of a postoperative small bowel obstruction. These two patients emphasize the limited resistance which premature infants exhibit to infection.

Associated conditions or anomalies are a factor in morbidity and mortality. The patient in case 2 had two separate obstructions in the duodenum, and case 3 involved a mongoloid infant. In all but one of the 11 patients in this series the obstructive lesion was of the complete type. Since this type is associated with marked physiological imbalance, early diagnosis is of paramount importance.

SUMMARY AND CONCLUSIONS

A newborn infant with a prepyloric diaphragm successfully treated is described, the second to be reported in the literature. Ten patients with congenital intrinsic obstruction of the duodenum have been operated on, and seven have survived. Seven of these 10 patients were premature infants. Two of the deaths occurred in premature infants weighing less than 3 pounds (1.3 Kg.). The other one involved a full term infant who died four days postoperatively after an anterior gastroenterostomy. Eight of the 11 infants were girls.

Prematurity, associated anomalies and other conditions play a major role in the morbidity and mortality in this group of infants. With earlier diagnosis and surgical correction, the prognosis for the infant with congenital intrinsic gastric and duodenal obstruction is more favorable than formerly, even though the infant is premature.

DISCUSSION

DR. E. H. FELL, Chicago: Two cases that we have seen at the Presbyterian Hospital in Chicago will be used to emphasize the points which Dr. Benson so well brought out.

[Slide] The first patient was seen by us 11 days after birth. On the eleventh day the child had received some barium sulfate by mouth, which, as Dr. Benson brought out, is not a good practice, and definitely increases the hazard to the child. The roentgenogram shows a markedly distended stomach, with no air in the lower part of the abdomen.

The next day, after food and fluids had been given in an effort to support the child, the abdomen was opened, and we found an obstruction at the outlet of the stomach. We could push bilelike material back and forth to this obstructing wall, and we could compress gastric contents down to this point. We opened the stomach and found normal gastric mucosa across the pyloric end of the stomach, completely blocking the outlet. We did an anterior gastroenterostomy.

[Slide] The child lived for five days. The postmortem examination revealed bilateral bronchopneumonia and a perforation at the site of anastomosis, with local peritonitis. This photograph is of a microscopic slide showing the wall of gastric mucosa, submucosa, muscularis and duodenal mucosa that formed the congenital atresia across the pyloric end of the stomach.

This, I believe, is a case similar to the one that Dr. Benson reported. In retrospect, perhaps we should have tried to excise the obstructing wall or should have performed an enteroenterostomy about the gastroenterostomy.

[Slide] The second infant to be considered was born at Presbyterian Hospital and was recognized in the first 24 hours as having a possible bowel obstruction. A flat plate of the abdomen was taken; it showed some air in the stomach and none in the lower part of the abdomen. Thirty-six hours after birth the roentgenogram showed an obstructive pattern of the small bowel; there was no air in the large bowel. We believe that giving barium sulfate by mouth is a dangerous and unnecessary diagnostic procedure but a thin barium mixture given carefully

by rectum often gives aid in differentiation of a malrotation from congenital small bowel lesions. This slide shows the large bowel to contain barium; it is normal in position, and its lumen is extremely small.

[Slide] At operation an atresia of the jejunum a little below the duodenojejunal junction was found, and just distal a complete aplasia of the bowel was present for 2 inches (5 cm.). After injection of sterile mineral oil into the bowel distal to the atresia the lumen was found to be patent through the ileocecal valve, and distention of the bowel with the oil made possible a technically easier anastomosis of the end of the large proximal bowel to the side of the distal bowel as shown in this slide. The child made a satisfactory recovery.

Early diagnosis and early operation are essential for a low mortality rate. Delay in diagnosis and treatment is associated with debility, distention and necrosis of the bowel and an unhappy termination.

Dr. Arthur R. Metz, Chicago: Dr. Benson's paper on the obstructions of the stomach and duodenum recalls an interesting case that came under my care in 1937. This case was reported at the fiftieth annual meeting of the Western Surgical Association, Topeka, Kan. Dec. 6, 1940.

A brief summary of the case reported is as follows: On the second day after birth a lump about 4 cm. in diameter developed in the upper part of a baby's abdomen. The infant also regurgitated all its food, showing that a mass had developed rather suddenly and apparently was obstructing the outlet of the stomach. Immediate operation was performed on the third day, and when the abdomen was opened a firm mass about 5 cm. in diameter was found to occupy the distal end of the stomach just proximal to the pylorus. An incision was made in the mass, which proved to be a cystlike structure from which a slightly turbid fluid escaped, having the appearance of gastric juice. In order to make an opening into the proximal portion of the stomach a second incision was made proximal to the mass, and it was found that a thin membrane was present which was perforated and enlarged by three radial incisions. In a similar way an incision was made in the duodenum; the distal septum was found to be very thin, and it was perforated and enlarged by three radial incisions, which established a continuous passage through the stomach into the duodenum. The three openings were then closed, and the infant continued taking nourishment without any further complication.

A portion of the septum was removed for microscopic examination, which showed it to have normal gastric glands on each side.

From the above findings it was evident that there was a double septum in the stomach, one just proximal to the pylorus and a second about 6 cm. proximal walling off a segment of gastric mucosa which, when it began to secrete, formed the cyst. The infant continued to grow and is now a healthy child 13 years of age. Follow up x-ray examination shows no evidence of the former obstruction.

At the time this case was under my care it was discussed with Dr. Albert Montgomery, who was especially interested in congenital defects in infants and who had never had such a problem. A careful search of the literature was made, but we were unable to find a similar case of such a problem reported at that time.

Dr. C. W. McLaughlin, Omaha: This excellent presentation by Dr. Benson discusses the one group in the whole field of intestinal obstruction which still carries a disturbing mortality rate. As he has shown, this rate has gradually fallen from 60 per cent down to approximately 30 per cent in recent years. When it is realized that these patients are premature infants with a congenital defect producing intestinal obstruction and that preoperative preparation cannot be done as in the adult patient, it is not surprising that the morality remains at such a high level.

We fully appreciate the underlying problems which tend to keep the mortality at such a distressing level. Progress is being made, but the plea should be for earlier diagnosis. These infants will hold for only a short time. They will stand an amazing amount of manipulative surgical procedure if the time interval between birth and operation is not prolonged. It is indeed gratifying to see a presentation of 11 cases with only three deaths, when this condition only a few years ago carried a 100 per cent mortality rate.

Dr. Clifford D. Benson, Detroit: I wish to thank Dr. Metz for bringing to my attention, at least, his case of obstruction in the stomach with two different septums. We overlooked it.

USE OF TANTALUM MESH IN HERNIA REPAIR

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THE REPAIR of large ventral or inguinal hernias, especially when there is a deficiency or absence of adequate fascia, has taxed surgical ingenuity for years. Fascial transplants, pedicled muscle or fascial flaps and vitallium plates [1] have all been tried. In recent years cutis grafts have been advocated and excellent results reported by several surgeons.[2] Cutis grafts require advance planning in many instances, and meticulous skin preparation is necessary to prevent infection, an ever present threat. Their use often prolongs the operation considerably and leaves another scar or deformity if a large graft has to be taken from a distant site. These objections do not apply to tantalum mesh, which can be always available for use in any hernia when it develops that some additional substance is necessary to effect an adequate repair. It would appear that the results from tantalum mesh repairs are at least as good as those from cutis grafts.

Our experiences with tantalum wire mesh or gauze [3] in the repair of difficult hernias have convinced us that this material is probably the best solution to the problem. It is supplied in sheets 6 by 12 inches (15 by 30 cm.) in size and made up of 0.003 inch (0.0076 cm.) tantalum wire in a fine (type 50) mesh. Pieces can be cut by scissors to any desired size or shape. Its flexibility allows it to be approximated readily to any surface. At present, each sheet costs approximately $25, but this price is not prohibitive when it is considered that one sheet is usually adequate for the repair of two or three large hernias or a dozen smaller ones. It can be repeatedly sterilized by autoclaving without affecting its consistency.

The fate of the mesh in the abdominal wall and the manner in which it aids in hernial repair have been studied in experimental animals. Koontz [4] resected large

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

1. McNealy, R. W., and Glassman, J. A.: Vitallium Plates Used in Repair of Large Hernias, Illinois M. J. **90**:170-173 (Sept.) 1946.

2. Cannady, J. E.: Some of the Uses of the Cutis Graft in Surgery, Am. J. Surg. **59**:409-419 (Feb.) 1943. Behrend, M., and Behrend, A.: Full Thickness Skin Graft in the Repair of Voluminous Hernias, J. Internat. Coll. Surgeons **13**:41-45 (Jan.) 1950. Vásquez, M. J.: Whole Skin Grafts for Repair of Abdominal Hernia and Eventrations, Prensa méd. argent. **36**:1283-1290; 1325-1339; 1396-1401; 1458-1461 (July) 1949.

3. Manufactured by the Ethicon Suture Laboratory, New Brunswick, N. J.

4. Koontz, A. R.: Preliminary Report on the Use of Tantalum Mesh in the Repair of Ventral Hernias, Ann. Surg. **127**:1079-1085 (May) 1948.

segments of the rectus muscle in dogs and covered the defect by tantalum mesh which then lay between peritoneum and subcutaneous fat. Within four to nine months he found the mesh to be covered by a thick, tough envelope of fibrous tissue which had grown through the mesh and become intimately adherent to it. "A firmer and more thorough-going closure of the defect can scarcely be imagined." Others [5] have noted the same infiltration of the mesh by fibrous tissue, either in experimental animals or in patients who required subsequent laparotomy through hernial sites previously repaired with mesh. It would appear that the growth of this tough fibrous tissue is stimulated by the mesh, which acts as a foreign body.

The development of this fibrous tissue has been noted as early as 14 days postoperatively.[5b] Within four to six weeks it is sufficiently firm to maintain the hernial repair.[5a] The ultimate fate of the mesh has been followed by means of x-rays, and fragmentation is usually noted in nine to 12 months. This breaking up is due to the process of "work hardening" of the metal and appears to have no effect on the integrity of the repair or the solidity of the surrounding fibrous tissue. The mesh thus appears to serve as a scaffold on which the fibrous tissue grows and probably serves no useful function after the development of the latter.

No patients in our series have noted any sensations attributable to the presence of the mesh, although it has been observed [5b] that a cardboard effect in the skin may be noted if the mesh is used immediately below a very thin subcutaneous fat pad. Stern [6] reported that bending of the mesh produced lumps below the skin in one of his patients, but that these were flattened out by the wearing of a belt. The fibrous tissue around the mesh gradually assumes the smooth flexible consistency of fascia, and no excessive nodularity has been palpable after about six months. This has been found true even in those patients in whom there was no possibility of a fascial closure, and the mesh was placed between peritoneum and subcutaneous fat. The solid abdominal wall which results after mesh repair of these large defects is gratifying to a patient whose life has been made bearable only by the constant wearing of a rigid, tight, canvas corset. Koontz [7] reports an excellent result in a child with a large defect due to congenital absence of the abdominal wall in the epigastrium.

Several authors have reported wound infections and postoperative purulent drainage, although the end result in these cases has been good. We are aware of only one patient in whom continued drainage from a wound infection made it necessary to remove the mesh.[8] We have felt it advisable to place one or two Penrose drains below the skin in patients who were extremely obese, when large pieces of the mesh were used and when the fascial repair was poor. On several

5. (*a*) de Brun, H. C. W. S.: Hernioplasty by Means of Tantalum Mesh, Mil. Surgeon **104**:128-131 (Feb.) 1949. (*b*) Lam, C. R.; Szilagyi, D. E., and Puppendahl, M.: Tantalum Gauze in the Repair of Large Postoperative Ventral Hernias, Arch. Surg. **57**:234-244 (Aug.) 1948. (*c*) Douglas, D. M.: Repair of Large Herniae with Tantalum Gauze: Experimental and Clinical Study, Lancet **1**:936-939 (June 19) 1948.

6. Stern, H. S.: Tantalum Gauze Repair of Incisional Hernia, J. Internat. Coll. Surgeons **13**:429-431 (April) 1950.

7. Koontz, A. R.: Further Experiences with the Use of Tantalum Mesh in the Repair of Large Ventral Hernias, South. M. J. **42**:455-460 (June) 1949.

8. Metz, A. R.: Personal communication to the authors.

occasions a rather profuse serous drainage has resulted, although this has never lasted over 10 days. We have had no wound infections or discharge of the non-absorbable suture materials (cotton or wire) which have been used to supplement the repair.

Patients with large ventral hernias have been advised to wear a supporting corset for two to three months postoperatively. No truss or corset has been advised or proved necessary after repair of inguinal hernias.

Our first experience with the use of tantalum mesh was in a 62 year old man who originally entered the hospital critically ill. Emergency laparotomy disclosed

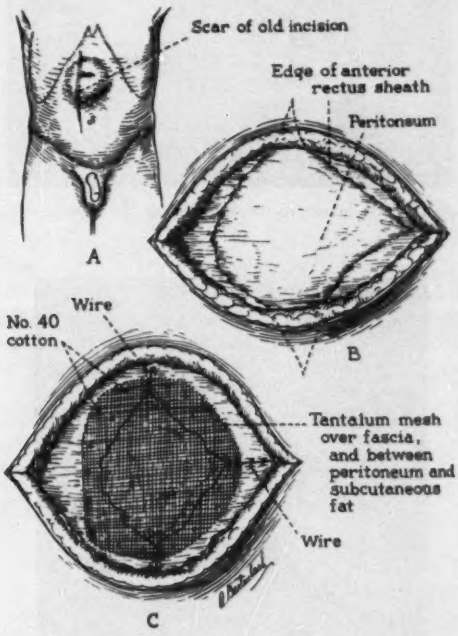

Fig. 1.—Manner in which tantalum mesh may be used to repair an abdominal wall defect in the absence of fascia.

diffuse prulent peritonitis, and the right rectus incision was enlarged by a transverse T extension to the left in order to reach and close a perforated gastric lesion lying high on the lesser curvature. A severe wound infection with fascial sloughing was followed by the development of a large epigastric ventral hernia. Three months later, persistence of gastric symptoms indicated gastric resection because of the suspicion of a malignant process. Through a transverse incision, a subtotal resection for a large benign ulcer was accomplished. The problem of repair of the hernia was then presented. The fascia could only be partially closed by wire sutures at the left side of the defect (fig. 1). The remainder of the defect was

closed by a large piece of tantalum mesh as shown, placed between peritoneum or omentum and subcutaneous fat. Fragmentation of the mesh 22 months later

Fig. 2.—Twenty-two months after tantalum mesh repair of the large epigastric hernia shown in figure 1.

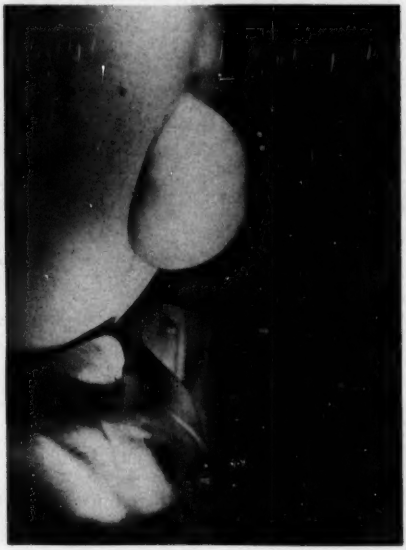

Fig. 3.—A large umbilical hernia.

occurred, although the repair was solid, no hernia existed and the patient enjoyed excellent health (fig. 2).

Other large ventral and umbilical hernias have since been successfully corrected (figs. 3 and 4). On occasions the mesh has been placed over closed transversalis

fascia, and partial closure of the anterior rectus sheath has been accomplished over it (fig. 5). In other patients the mesh has been placed over the closed anterior fascial layer. We have usually attempted to place the mesh between fascial layers, at least partially, but this does not appear to be of great importance in the end result. We have not covered exposed mesh by fascial transplants, as has been advocated by some [5a] and do not believe this is necessary. The edges of the mesh may be reinforced by folding over to make a double layer (fig. 6). In all cases,

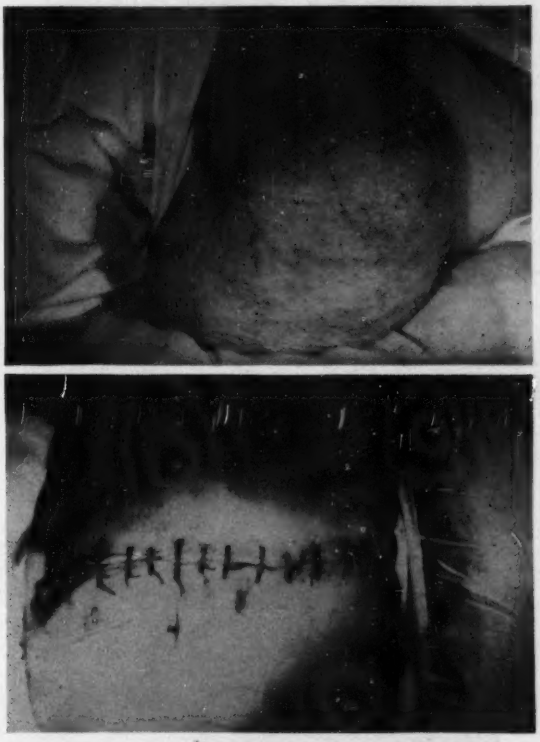

Fig. 4.—A very large postoperative ventral hernia and the appearance of the wound immediately after repair with tantalum mesh. Note Penrose drains.

the mesh has been sutured into position by interrupted no. 40 cotton sutures. Folding and wrinkling of the mesh (fig. 6) have not affected its efficiency.

In the repair of large and recurrent inguinal hernias the mesh has been used in various ways as illustrated in figures 7 and 8. The only effective way to close the canal completely is by removal of the cord and testicle (fig. 9), and this was frequently done in the large inguinal hernias in older men.

Early ambulation within 24 hours has been insisted on in all these patients, and no significant complications have occurred. A total of 42 patients have now been

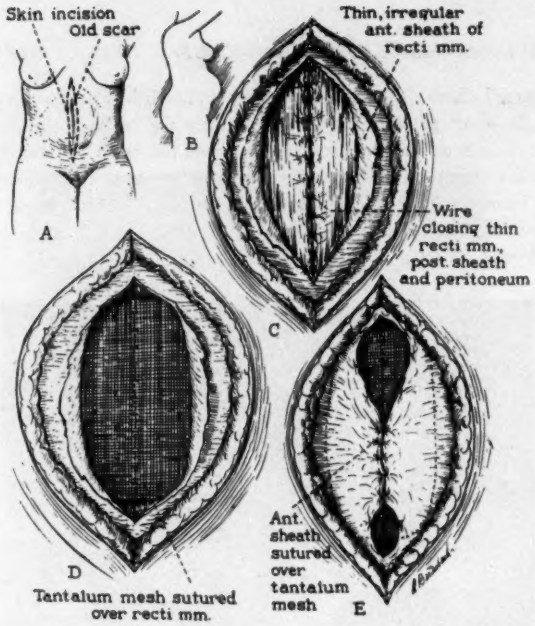

Fig. 5.—Use of tantalum mesh in a ventral hernia where the anterior fascial layer cannot be completely closed.

Fig. 6.—The edges of the mesh may be folded over to aid in suturing of it to fascia. Wire sutures are used to close fascial layers.

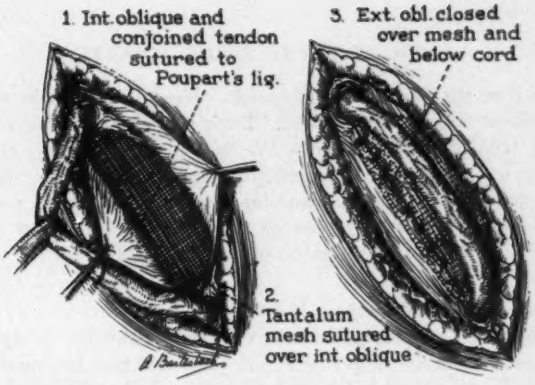
1. Int. oblique and conjoined tendon sutured to Poupart's lig.
3. Ext. obl. closed over mesh and below cord
2. Tantalum mesh sutured over int. oblique

Fig. 7.—Repair of inguinal hernia. Here the mesh lies between internal oblique muscle and fascia of external oblique muscle.

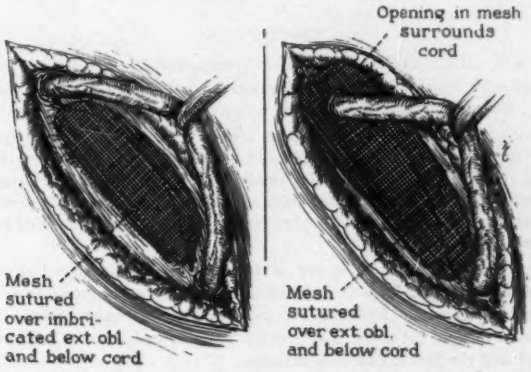
Opening in mesh surrounds cord
Mesh sutured over imbricated ext. obl. and below cord
Mesh sutured over ext. obl. and below cord

Fig. 8.—Repair of inguinal hernia. Here the mesh is placed over the fascia of the external oblique, which may or may not be imbricated. An opening may be cut in the mesh so that it surrounds the cord. Replacement of the cord on the mesh has given no disagreeable results.

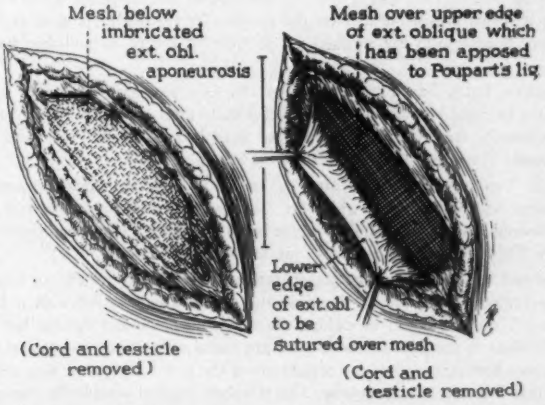
Mesh below imbricated ext. obl. aponeurosis
Mesh over upper edge of ext. oblique which has been apposed to Poupart's lig.
Lower edge of ext. obl. to be sutured over mesh
(Cord and testicle removed)
(Cord and testicle removed)

Fig. 9.—Repair of inguinal hernia using tantalum mesh after removal of cord and testicle. The mesh may be buried below the imbricated external oblique fascia or placed between its layers. The Cooper ligament technique may be used if desired.

operated on with the use of tantalum mesh. These include large and recurrent ventral, umbilical and inguinal hernias. During this two year period, 260 other hernias have been operated on by us. We have restricted the use of the mesh to those cases in which it appeared that adequate repair could not be effected without it. All 42 patients have been followed for periods ranging from a few weeks to two years. To date there have been no recurrences. Our results have been so gratifying that we feel that this method of repair of difficult hernias can be highly recommended.

SUMMARY

Forty-two patients with large or recurrent ventral, umbilical or inguinal hernias have been operated on over a period of two years and tantalum mesh used in the repair. Mesh can be placed between peritoneum and skin where no fascia exists and a successful correction of a ventral hernia accomplished. There have been no wound infections, no disagreeable after effects and no recurrences to date.

DISCUSSION

DR. ARTHUR R. METZ, Chicago: I wish to compliment Dr. Guy on the excellent results that he has had with apparently few complications. I have avoided foreign material such as tantalum mesh, wires or nonabsorbing sutures, as surgical gut has served me well.

There recently came under my observation a man who had a persistent drainage from a hernia incision in which x-rays showed a piece of tantalum mesh about 1 inch (2.5 cm.) square which had been used. The gauze had been sutured in place with silk, and drainage had persisted for over six months. The patient insisted that something be done, and the wound was opened and the tantalum gauze along with silk sutures removed, after which the wound healed promptly and has remained closed since.

Another patient was seen as a matter of routine examination who had previously been operated on elsewhere, with a large sheet of tantalum gauze used to repair an incisional hernia. The gauze was approximately 10 by 12 cm. in size. In x-ray examination there was found extensive fragmentation of the mesh. The patient, however, had no local symptoms, the wound was well healed and the hernia had been retained.

I note that in some of Dr. Guy's roentgenograms he also shows fragmentation of the gauze, which apparently happens as a result of frequent movements, but the fascia fills in enough to give the necessary support.

After hearing Dr. Guy's paper I may be tempted to use tantalum gauze in some future case in which it seems impossible to meet the problem by the overlapping of fascia. However, to date we have been able to use surgical gut in suturing the fascia and they have held satisfactorily.

DR. H. GLENN BELL, San Francisco: Has Dr. Guy had any experience using tantalum mesh to repair a perineal hernia that occurs occasionally after an abdominal perineal resection? As far as the ventral hernias are concerned, we have had experience with four with the use of tantalum mesh. The results have been good so far.

DR. TOM D. THROCKMORTON, Des Moines, Iowa: I have used tantalum gauze since 1944 and would like to add that the data which Dr. Guy has presented to you entirely coincide with my own experiences. Among the tantalum gauze herniorrhaphies I have done there has been only one recurrence. This recurrence was due to my error.

The patient had an extremely large postoperative ventral hernia which ran from the xiphoid process to the region of his internal inguinal ring. This was repaired with a large piece of tantalum gauze. I was interested in making the repair adequate and sutured the upper end of the tantalum implant to the periosteum of the right costal arch. Along the lateral border of the implant I took two firm stitches into the periosteum of the anterior-superior iliac spine. I believe, in retrospect, that this was a sad mistake. The tantalum implant completely shattered and tore

from the region of the anterior-superior iliac spine because as the patient, a laboring man, would extend himself the implant was firmly attached between two relatively immobile structures, i. e., the costal margin and the anterior-superior iliac spine. I would therefore urge that when large implants of tantalum gauze are used in herniorrhaphy in an area subjected to a good deal of motion they not be anchored to firm, immobile structures. As a rule I have not used drains after herniorrhaphy. Three of my cases have had some drainage, but I do not believe more than one might expect in any large ventral herniorrhaphy with wide undermining of skin flaps. I have usually applied a pressure type of dressing, which has, on the whole, adequately taken care of serum accumulations in the wound. Regarding perineal hernia, I have operated on one, with a good result so far.

As regards the over-all prospects for tantalum gauze herniorrhaphy, eight of my patients have now for more than five years had no evidence of recurrence.

Dr. Chester C. Guy, Chicago: In answer to Dr. Bell, I have never used this mesh in the repair of a perineal hernia. Dr. Throckmorton wrote one of the earliest contributions in the literature on the use of tantalum mesh.

BENIGN DUODENOCOLIC FISTULA

C. SHERRILL RIFE, M.D.
MILWAUKEE

A CASE OF benign duodenocolic fistula is presented chiefly because of its rarity, it being the eighth recorded case in the literature covering the period since 1885. It is interesting that seven of the eight patients reported on have survived operation and recovered.

The first case, reported by Rees [1] in 1933, was that of a duodenocolic fistula associated with an incompetent sphincter of Oddi. It was thought that the fistula developed as a result of perforation from a typhoid ulcer 28 years previously. Recovery was complete after operation.

McPeak [2] reported two cases in 1940. The first patient survived for six years after closure of the fistula. Though no tissue was removed for microscopic examination, the lesion was likely benign. The second patient died on the twelfth postoperative day from peritonitis. Autopsy confirmed the clinical impression of a benign fistula. It was thought that both patients had had a duodenal ulcer which perforated into the transverse colon.

McClinton [3] added a fourth case in 1944, also the result of a perforated ulcer. Recovery was complete after operation.

Ogilvie [4] presented the fifth and sixth cases in 1949. In each case the cause of the fistula was found to be a caseating tuberculous lymph node which had ulcerated into the duodenum and colon. Both patients recovered after closure of the fistulas.

Krock, in discussing Ogilvie's paper, reported a seventh case with a 23 year history suggestive of an abnormal communication between the upper and lower parts of the gastrointestinal tract. At operation a fistula was found between the second part of the duodenum and the hepatic flexure of the colon. Recovery was uneventful after closure of the fistula.

REPORT OF A CASE

The patient, a man 45 years of age, was admitted to the hospital complaining of intermittent diarrhea of about four years' duration. He had had six to eight watery stools each day during the episodes of diarrhea and had occasionally noticed undigested food in the stools as soon

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

1. Rees, C. E.: Duodenocolic Fistula with Incompetent Sphincter of Oddi, J. A. M. A. **100**:496-497 (Feb. 18) 1933.

2. McPeak, C. N.: Benign Duodeno-Colic Fistula, with Report of 2 Cases, Radiology **34**: 343-350 (March) 1940.

3. McClinton, J. B.: Non-Malignant Duodeno-Colonic Fistula, Canad. M. A. J. **51**: 434-436 (Nov.) 1944.

4. Ogilvie, H.: Non-Malignant Duodeno-Colic Fistula, Ann. Surg. **131**:899-902 (June) 1950.

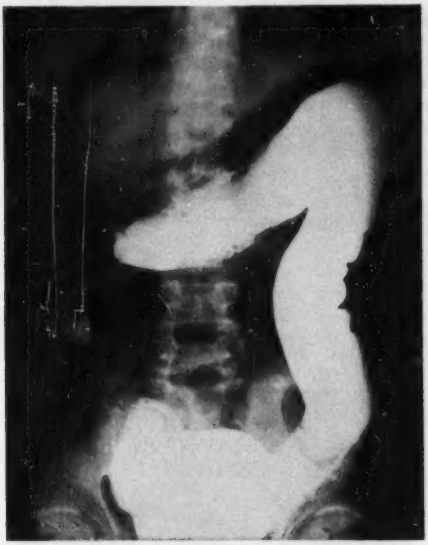

Fig. 1.—Barium enema showing filling defect in proximal transverse colon. Cecum lies high. Air in stomach just above transverse colon.

Fig. 2.—Postevacuation roentgenogram showing a small amount of barium in the stomach.

as one hour after eating. At no time had there been a history of abdominal pain or any other symptoms that might be attributable to an ulcer. There were no foul-smelling eructations. The total weight loss was 50 pounds (22.7 Kg.), though his weight had been stationary for about a year. He had not undergone an abdominal operation. Because of the four year duration of the illness, it was thought that his lesion was probably benign. The patient stated that he knew the diagnosis, made by roentgenologic examination four years previously, to be "a communication between the upper and lower intestine." He had been told that this condition could not be helped by operation.

Physical Findings.—The patient was pallid and emaciated and appeared much older than his 45 years. General physical and abdominal examinations were otherwise noncontributory.

Laboratory Findings.—The hemoglobin content was 75 per cent (11.5 Gm. per 100 cc.), the red blood cell count 3,620,000, the white blood cell count 8,400 and the differential count normal. The total serum protein level was 6.2 Gm. per 100 cc., with albumin 4.1 Gm. and globulin 2.1 Gm., and the nonprotein nitrogen was 28 mg. per 100 cc. The cephalin flocculation test gave a negative reaction at 24 hours and at 48 hours. The urine was normal.

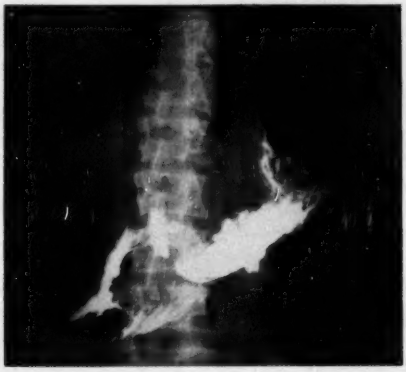

Fig. 3.—Roentgenogram of upper gastrointestinal tract. Fistula extends downward from junction of second and third portions of stomach.

Roentgenologic Findings.—Examination of the colon after a barium enema showed a filling defect on the right side of the transverse colon (fig. 1) about 10 cm. long. There was an irregular stricture of the mucosa. On the colon-emptying roentgenogram (fig. 2) some barium sulfate was seen to lie in the stomach, and the fistulous tract appeared to extend from the right transverse colon into the duodenum. Examination of the stomach two days later showed it to be normal. The duodenal cap was deformed. The second portion of the duodenum was greatly widened, and at its junction with the third portion there was a filling defect with a fistulous tract about 3 cm. long which connected directly with the colon (fig. 3). Most of the barium sulfate was seen to go through the duodenum into the jejunum, however. There was no evidence of filling of the biliary tree or the gallbladder. A roentgenogram of the gallbladder showed normal visualization without evidence of stone.

Preoperative preparation consisted of administration of a high caloric, high protein diet, multiple vitamins, 1,000 cc. of blood, succinylsulfathiazole, (sulfasuxidine®) 15 Gm. daily in divided doses for four days, cleansing enemas and gastric suction for 24 hours prior to operation.

Operation was carried out on July 15, 1949. A transverse incision was made just above the umbilicus, transecting the right rectus and the medial half of the left rectus muscle. The liver, gallbladder and common duct appeared and felt normal. The gallbladder was distended with bile and emptied on pressure. The patient had an undescended cecum, which lay directly

over the junction of the second and third parts of the duodenum. A firm mass involved the duodenum and the transverse colon just distal to the cecum (fig. 5). Approach to the mass was made by cutting the lateral peritoneal reflection of the cecum and lifting it medially. The duodenum was separated from the mass, which left an opening about 2 cm. long in the former. This opening was just above the papilla of Vater, and bile could be seen coming from it. The

Fig. 4.—Roentgenogram taken one half hour after that shown in figure 3. A small amount of barium has passed into the transverse colon. Most of the barium is in the stomach and the proximal jejunum.

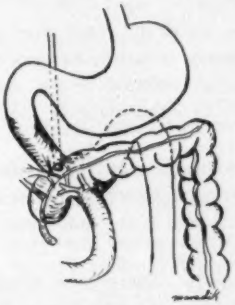

Fig. 5.—Schematic drawing showing relation of duodenum to transverse colon as seen at operation. Cecum undescended. Terminal portion of ileum extends downward.

duodenum was closed in its transverse axis. The mass was then removed en bloc. No attempt was made to dissect out the fistula at the operating table. The tissue removed included the terminal portion of the ileum, the cecum, the inflammatory mass containing the fistula and part of the transverse colon. The terminal part of the ileum was large and the transverse colon small. An end to end anastomosis was done between the ileum and the transverse colon. The immediate postoperative course was uneventful.

Gross Pathologic Findings.—The fistula between the duodenum and the colon was 0.5 cm. in diameter and 2 cm. long. The tract was lined by necrotic tissue. There were focal ulcerations of the mucosa, with underlying zones of chronic inflammation of a nonspecific nature. No neoplasm was present. The ileocecal opening was much narrowed, being only 1 cm. in diameter, and protected by a rudimentary ileocecal valve, which consisted simply of a small fold of the mucosa. The aperture between the cecum and the transverse colon where the fistula entered the colon was also narrowed, being about 1 cm. in diameter.

The patient gained rather slowly after operation and was not entirely well until about three months postoperatively. During this period there was considerable edema of the lower extremities, which was presumed to be on a nutritional basis but which cleared up promptly with the administration of a low salt diet and ammonium chloride. Laboratory studies done seven weeks postoperatively gave the following results: The hemoglobin content was 11.5 Gm. per 100 cc., the red blood cell count 3,610,000, the white blood cell count 9,500 and the differential count normal. The sedimentation rate revealed a 45 mm. drop in one hour. The nonprotein nitrogen level was 41 mg. per 100 cc., blood sugar level 82 mg., creatinine 2 mg. and total protein 6.89 Gm., with albumin 4.18 Gm. and globulin 2.71 Gm., a ratio of 1.54 to 1. The urine was normal except for a trace of albumin and an occasional hyaline cast.

The patient was last seen in October 1950, about 15 months after operation. He had gained 65 pounds (29.5 Kg.) and was in excellent health. The blood picture, renal function and liver function were essentially normal. There were no symptoms to suggest reactivation of a duodenal ulcer.

COMMENT

This fistula was probably the result of an ulcer of the second part of the duodenum which perforated into the transverse colon. Ulcers in the second and and third parts of the duodenum are probably commoner than is generally realized, but accurate statistics regarding their incidence are difficult to obtain. Ulcers beyond the first part of the duodenum are difficult to show roentgenologically and are therefore not operated on unless they perforate. Patients with this condition may or may not give a history of abdominal pain or of any of the other symptoms of ulcer. Diarrhea, weight loss and voracious appetite constitute the typical symptoms. No author listed the foul eructations which one usually observes with gastrocolic fistula.

In my opinion, the patient's fistula did result from a perforated duodenal ulcer. Evidence to support this hypothesis is that he has a deformity of the duodenal cap, and duodenal ulcers are commonly multiple. He is also constitutionally the "ulcer type" of person. Other possibilities that must be thought of in such cases are as follows:

1. Diverticulum of the duodenum with inflammation and perforation. This possibility would appear unlikely, inasmuch as practically all duodenal diverticuli are located on the posteromedial wall of the duodenum in close relationship to the pancreas.

2. Perforating ulcerative colitis. There is no record of a single duodenocolic fistula on this basis. In 1939 Ormandy and Bargen [5] reported that at autopsy a patient with ulcerative colitis had multiple fistulas between the stomach, duodenum and colon.

3. Caseating tuberculous lymph node (Ogilvie).

4. Perforating typhoid ulcer (Rees).

5. Ormandy, L., and Bargen, J. A.: Thrombo-Ulcerative Colitis Associated with Cologastric and Coloduodenal Fistulas, Proc. Staff Meet., Mayo Clin. **14**:550-552 (Aug. 30) 1939.

SUMMARY

A case of benign duodenocolic fistula is presented. It is the eighth case recorded thus far. The fistula probably resulted from perforation of an ulcer of the second part of the duodenum into the transverse colon. Recovery was complete after operation. Brief comments are made concerning the seven cases reported by other authors.

DISCUSSION

DR. HENRY K. RANSOM, Ann Arbor, Mich.: Because of the rarity of this condition, I should like to call attention to two cases which we have seen. They may be properly classified as cases of benign duodenocolic fistulas, although the cause is different than that in the case just discussed. Our first patient, seen in the summer of 1946 was a man of 28 who entered the hospital because of chronic diarrhea, bloody stools weight loss and weakness. He previously had undergone a sigmoid colostomy for what was said to be a stricture of the rectum. On examination, the lesion in the rectum was found to be not neoplastic but obviously an old inflammatory process. Clinically, this patient exhibited the picture of chronic ulcerative colitis. This diagnosis was borne out in the roentgen study.

[Slide] This film on the screen shows the study of the colon with barium sulfate, first given by rectum, which method did not give informative results, and then given through a catheter introduced into the sigmoid colostomy. It is obvious that the patient had chronic ulcerative colitis, with the characteristic changes, and that the sigmoid colostomy had been an ill advised operation for total ulcerative colitis.

As the examination continued, one could see the short colon, with narrowing of the lumen and the smooth outline of the walls. There was ampullary dilatation in the midtransversus, but at a point just proximal a strange appearance was noted, i. e., there was a rapid spread of barium sulfate into what was obviously the small bowel and, as the examination continued, upward into what appeared to be the stomach.

This next film shows essentially the same thing. More barium has been given, and there is more filling of the small bowel. It was thought that there was an abnormal communication at the level of the proximal transverse colon and the duodenum. The examination was repeated and these same findings obtained. It was never possible to demonstrate clearly a communication between the duodenum and the colon when barium was given by mouth.

This patient was later operated on, and at first an ileostomy was established. After his condition improved a subtotal colectomy was performed. At the time of the subtotal colectomy, just as one would anticipate from the barium studies, a definite fistulous communication between the duodenum and the proximal transverse colon was identified. This was separated, and in the resection of the colon the opening in the duodenum was closed and the colon removed down to the upper portion of the rectum. Subsequently the operation was completed by a combined abdominal-perineal resection. Microscopic studies of all the tissue confirmed the diagnosis of chronic ulcerative colitis.

A similar situation was seen a year ago, in a boy of 12. He had not undergone a colostomy, but he had the characteristic symptoms of chronic ulcerative colitis, weight loss, pallor and bloody diarrhea.

[Slide] The roentgenologic studies here show comparable findings. The ampullary region of the rectum is not abnormal, but as one follows the pattern of the barium sulfate upward there is the characteristic deformity or irregularity of the descending colon and the transversus as far as the barium passed. Then the same phenomenon was observed.

As more barium sulfate was given, there was an escape into the small bowel, with rapid filling of a coil of small intestine, which was again interpreted as upper small intestine, probably jejunum. This patient also was treated surgically; as in the first case, an ileostomy was carried out. The subsequent subtotal colectomy was performed at the appropriate time after rehabilitation of the patient, and again the same finding was encountered—a fistulous communication between the duodenum and the colon which had been anticipated and demonstrated roentgenologically. However, a second fistula occurring between the upper part of the jejunum and the upper part of the descending colon was encountered at this time, which had

not been demonstrated preoperatively. The inflammatory reaction was so great that a segmental resection of the jejunum was necessary, with closure by an end to end anastomosis.

This patient also survived. Microscopically, the specimen showed chronic ulcerative colitis. The patient still has the rectum in situ, with the hope that possibly some time restoration of bowel continuity will be possible.

The symptoms in these two cases have been predominately those of ulcerative colitis, and, while it is impossible to say whether the spill of duodenal contents into the colon was responsible for some of the weight loss and the diarrhea, I believe that one could adequately explain the symptoms in our patients on the basis of the chronic ulcerative colitis alone.

Dr. J. M. Winfield, New York: Because of the rarity of this condition and the few cases reported in the literature, I think it is worth while mentioning an additional case.

A man was admitted to the Metropolitan Hospital in April 1950, complaining of symptoms rather analogous to those that Dr. Rife delineated. Seven years before we saw him an emergency operation had been performed for "an acute abdomen." A transcript from that hospital could not be obtained. He did not know exactly what had been done, but he knew that no viscera had been removed. A cerebrovascular accident resulted in hemiplegia.

[Slide] Barium meal was not of diagnostic value. A barium enema definitely showed good filling of the colon and, simultaneously, passage of the barium sulfate into the stomach and then into the small intestine in this area. You will note the tenting here of the sigmoid colon, presumably where the fistula originated; this presumption was later confirmed.

At the time of laparotomy there were large numbers of lymph nodes in the mesenteries of the intestines. Many of these were calcified. A fistula was found from the midsigmoid to the third portion of the duodenum, approximately 3 to 4 cm. in length, and on section the lumen was about 0.5 cm. in diameter.

Microscopic section of the specimen was reported as showing inflammatory tissue. There was no specific or definite evidence of tuberculosis. This man had either had a tuberculous lymphadenitis or some nonspecific lesion which produced an abscess and then fistula formation. He is now alive and well, without symptoms.

Dr. Robert Zollinger, Columbus, Ohio: I should like to reemphasize the factor of nutrition in patients having a fistulous communication between the upper and lower parts of the gastrointestinal tract. Dr. Rife has presented an interesting case which parallels closely the problem of nutrition in patients with gastrocolic fistula. We have observed such a patient who gained weight rapidly while on a high protein diet along with the usual dosage of sulfasuxidine.® In a period of three or four weeks the patient gained 15 pounds (6.8 Kg.) or more. Fat balance studies showed that a patient with a gastrojejunocolic fistula loses about 70 per cent of his fat or, in other words, absorbs only about 30 per cent of the fat which he ingests by mouth. After the administration of sulfasuxidine® the absorption of fat increased to almost 90 per cent. This observation, together with similar findings in an additional case, suggests that prolonged treatment with a high protein, high vitamin diet and sulfasuxidine® by mouth will bring the patient to operation in a much better condition as a result of better utilization of fat, which in turn provides a rich source of calories.

This finding may mean that a loss of food directly from the stomach or duodenum into the colon is not of as great importance as had been previously thought. Perhaps altered bacterial flora in the small bowel as a result of reflex of colonic contents is the major factor in the decreased absorption of food in these cases.

SEPARATIONS OF ABDOMINAL WOUNDS

CHARLES W. MAYO, M.D.
AND
MADISON J. LEE JR., M.D.
ROCHESTER, MINN.

SEPARATION of the wound following an abdominal operation, although infrequent, is a serious complication. An incomplete separation may involve deeper structures, with overlying skin and subcutaneous tissues healing, and a ventral hernia usually results. The wound may separate superficially, with peritoneum intact; a secondary closure or a long period of convalescence during healing by secondary intention ensues and a ventral hernia may develop. The most dramatic complication subsequent to laparotomy is complete separation of the wound, with or without evisceration. The high mortality rate and the heavy cost in time and money to surviving patients are distressing.

Dehiscence, disruption and eventration are synonymous terms used to denote complete separation of an abdominal wound. Continued emphasis on the causes of failure of wound healing is warranted, in an effort to lower the incidence and mortality rate. We are presenting data resulting from a study of cases of wound disruption occurring during two five year periods at the Mayo Clinic. No attempt is made to recapitulate all findings and divergent opinions summarized in the literature.[1]

CASES STUDIED

Cases included in this study of separation of the wound involve all layers of the abdominal wall. All cases in which secondary closure of the abdomen was effected in the operating room with the patient under anesthesia are included. Records of patients treated by taping of the abdomen in the patient's room are not complete and such cases are not included.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Nov. 30, 1950.

1. Bobrow, M. L.: Postoperative Evisceration: A Résumé of the Literature and Report of 5 Cases, Am. J. Surg. **54**:682-690 (Dec.) 1941. Bowen, A.: Postoperative Wound Disruption and Evisceration: An Analysis of 34 Cases, with a Review of the Literature, ibid. **47**:3-19 (Jan.) 1950. D'Ingianni, V.: Postoperative Evisceration: Comparative Study, New Orleans M. & S. J. **98**:65-72 (Aug.) 1945. Glenn, F., and Moore, S. W.: Disruption of Abdominal Wounds: Continuation of Previous Report, Surg., Gynec. & Obst. **72**:1041-1046 (June) 1941. Green, J. A.: Wound Disruption and Postoperative Hernia, J. Internat. Coll. Surgeons **3**:173-180 (April) 1940. Hartzell, J. B., and Winfield, J. M.: Disruption of Abdominal Wounds: Collective Review, Internat. Abstr. Surg. **68**:585-601, 1939. Jenkins, H. P.: A Clinical Study of Catgut in Relation to Abdominal Wound Disruption, with Test of Its Tensile Strength on Patients, Surg., Gynec. & Obst. **64**:648-662 (May) 1937. Joergenson, E. J., and Smith, E. T.: Postoperative Abdominal Wound Separation and Evisceration, Am. J. Surg. **79**:282-287 (Feb.) 1950. Walton, F. E.: Prevention and Treatment of Wound Dehiscence, Arch. Surg. **57**:217-226 (Aug.) 1948.

Two five year periods were selected for comparison to evaluate the effect of newer anesthetics, antibiotics, free use of blood, improved control of fluid and electrolyte balance and gastric tube with suction on the mortality rate in this catastrophic complication. During the years 1925 through 1929, period I, there were 52 cases of abdominal wound disruption at the clinic with secondary closure of the abdomen, and during the years 1945 through 1949, period II, there were 94 cases.

GENERAL FACTORS

Incidence.—In the literature are reported incidences of dehiscence varying from 0.2 to 2 per cent, but they are not comparable because the proportion of different types of operation varies widely. Dehiscence may follow any laparotomy, but the occurrence is more frequent after operations on the stomach, colon and biliary tract than after other abdominal operations. The incidence of wound disruption with secondary closure after these operations can be given for the years 1945 through 1949. In almost 5,500 cases with operation on the stomach there were 30 cases with dehiscence, an incidence of 0.55 per cent. In more than 7,200 cases with operation on the colon there were 33 cases of wound disruption, 0.46

TABLE 1.—*Comparison of Incidence and Mortality by Operations*

Dehiscence After Operations on	1925-1929			1945-1949		
	Total Cases	Deaths		Total Cases	Deaths	
		No.	%		No.	%
Stomach	24	4	16.7	30	6	20.0
Colon	8	5	62.5	33	8	24.2
Biliary tract	16	7	43.7	20	2	10.0
Miscellaneous	4	2	50.0	11	1	9.1
Total	52	18	34.6	94	17	18.1

per cent. In about 7,600 cases with operation on the biliary tract there were 20 instances of dehiscence, 0.26 per cent. Comparable figures are not available for period I. The number of cases following operation on these abdominal viscera in both periods is given in table 1. Although many pelvic operations were performed, there were but 2 wound disruptions during period I and none during period II after such operations.

Age.—The distribution of cases by age in both periods is given in table 2. The literature reports an average age of about 44 years. The average age of patients in period I was 52.5 years, and in period II it was 54.1 years. The patients' ages ranged from 20 years to 70 years in period I and from 1 week to 83 years in period II. One might expect that wound separation would be a complication of old age. Although more cases occur in older than in younger age groups, more operations on the stomach, colon and biliary tract are performed on older persons. Dehiscence occurs at all ages. The relatively greater strength of abdominal muscles is a factor in wound separations occurring in younger persons.

Sex.—The distribution by sex in both periods is presented in table 2. Most series report a predominance of males. The ratio of males to females of 6:1 in period I and 8:1 in period II is higher than that previously reported. Abdominal breathing, greater physical activity and less elasticity of the abdominal wall are

factors cited by Tashiro [2] which contribute to male predominance, a conclusion with which we agree. We add that childbearing and the use of corsets or girdles by women often result in a more elastic abdominal wall.

Season.—A study of the distribution in both periods by month, season and year revealed no significant variation in the occurrence of wound disruptions.

SYSTEMIC DISORDERS

Malnutrition.—Lack of proper nutrition in indigent patients, those with obstruction to the passage of food, patients with carcinoma and all debilitated patients has been ascribed a role in the failure of wound healing.

Thompson, Ravdin and Frank [3] and other authors [4] have emphasized the effect of hypoproteinemia. Adequate protein is necessary for optimal wound repair. However, wound disruptions will continue to occur in patients with excellent nutrition. Conversely, even among patients with the poorest nutrition the wound usually heals without difficulty. Perhaps one should conclude that with poor nutrition a less potent precipitating cause is necessary to disrupt a wound. In 66 of 94

TABLE 2.—*Incidence by Age and Sex*

	1925-1929				1945-1949			
			Total				Total	
Age, Yr.	Males	Females	No.	%	Males	Females	No.	%
29 or less	0	3	3	5.8	4	2	6	6.4
30-39	5	2	7	13.4	6	0	6	6.4
40-49	11	0	11	21.2	13	2	15	15.9
50-59	10	1	11	21.2	27	3	30	31.9
60-69	17	2	19	36.5	27	2	29	30.9
70+	1	0	1	1.9	6	2	8	8.5
Total	44	8	52	100.0	83	11	94	100.0
Per cent	84.6	15.4	100		88.3	11.7	100	
Average age	54.5	41.3	52.5		54.5	51.4	54.1	

cases during the years 1945 through 1949 serum protein levels were obtained at the time of dehiscence. In 15 cases (22.7 per cent) the serum protein level was 6.5 Gm. per 100 cc. or higher (6.5 Gm. per 100 cc. is normal); in 12 cases (18.2 per cent) the level was 6.0 through 6.4; in 13 cases (19.7 per cent) the level was 5.5 through 5.9; in 19 cases (28.8 per cent) the level was 5.0 through 5.4, and in 7 cases (10.6 per cent) the level was less than 5.0. Most patients were in reasonably good nutritional status before operation. Even in retrospect, one seldom could suspect from the state of nutrition that in these cases the wounds would disrupt.

From experimental and clinical evidence, lack of vitamin C has a role in postoperative wound separation.[5] While it is undoubtedly a factor, here again one is

2. Tashiro, S.: Wound Disruption: A Study of 55 Cases at the Cincinnati General Hospital, Surg., Gynec. & Obst. **78**:487-496 (May) 1944.

3. Thompson, W. D.; Ravdin, I. S., and Frank, I. L.: Effect of Hypoproteinemia on Wound Disruption, Arch. Surg. **36**:500-508 (March) 1938.

4. Efskind, L.: On Post-Operative Rupture of Laparotomy Wounds, Acta chir. Scandinav. **89**:563-578, 1944.

5. Kraybill, W. G.: Total Disruption of Surgical Wounds of the Abdominal Wall, with Reference to Plasma Proteinemia and Plasma Ascorbic Acid, Am. J. Surg. **66**:220-223 (Nov.) 1944. Lund, C. C., and Crandon, J. H.: Ascorbic Acid and Human Wound Healing, Ann. Surg. **114**:776-790 (Oct.) 1941.

confronted by the infrequent occurrence of dehiscence in patients with comparable avitaminosis C. Only two patients in period II had ascorbic acid levels determined, and in neither instance was the level significantly low.

Carcinoma.—A high incidence of carcinoma in dehiscence has been noted in many reports, with an average of about 25 per cent. Carcinoma was present in 16 cases (30.8 per cent) in period I and in 37 cases (39.4 per cent) in period II.

Obesity.—Difficulty in securing a satisfactory closure of the incision, increased intra-abdominal pressure from deposition of fat in the omentum and mesentery and tension on the suture line produced by the weight of subcutaneous fat rolling to all sides, rather than a metabolic disturbance, contribute to dehiscence in obese patients. In period I there were 7 obese patients (13.5 per cent) and in period II 21 obese patients (22.3 per cent), with no adequate explanation for the increased incidence. Some cases may have been related to technical details in the closure.

Miscellaneous.—Diabetes, syphilis, tuberculosis and jaundice have been blamed for dehiscence, but controlled studies to confirm this conclusion were not found.

TABLE 3.—*Systemic Disorders*

Systemic Disorder	1925-1929		1945-1949	
	No.	% *	No.	% †
Carcinoma	16	30.8	37	39.4
Obesity	7	13.5	21	22.3
Diabetes	1	1.9	4	4.3
Syphilis	2	3.8	4	4.3
Tuberculosis	0	0	2	2.1
Jaundice	3	5.8	4	4.3
Edema	2	3.8	0	0
Radiation burn	1	1.9	0	0

* Per cent of 52.
† Per cent of 94.

It will be noted that these conditions (table 3) occurred in occasional patients, but their role is indefinite.

OPERATIVE FACTORS

Anesthesia.—Anesthesia has an important indirect bearing on the occurrence of dehiscence. The individualization of an anesthetic agent and its skilful administration are necessary to obtain proper relaxation of the abdominal wall, adequate exposure without trauma and closure of the incision without tension. Curare and the endotracheal tube are valuable assets to help achieve these aims. Inhalation anesthetics should rarely be used for abdominal operations necessary in the presence of pulmonary disease. Aspiration of bronchial secretions should be performed as indicated.

Incision.—The type of incision has been credited with a major role in wound separation,[6] and many authors advocate a greater use of such anatomic incisions as the transverse, Sloan, Kocher, McBurney, Pfannenstiel and others. Studies such

6. DeCourcy, J. L.: Choice of Incision in Gall-Bladder Surgery as Factor in Preventing Wound Disruption, Evisceration and Herniation, Surg., Gynec. & Obst. **79**:606-610 (Dec.) 1944. Meleney, F. L., and Howes, E. L.: Disruption of Abdominal Wounds with Protrusion of Viscera, Ann. Surg. **99**:5-13 (Jan.) 1934.

as that of Singleton and Blocker [7] show a higher incidence of dehiscence in longitudinal incisions than in anatomic incisions. However, better exposure and better exploration of certain areas of the abdomen can be obtained through a vertical incision in some cases. It is our policy to fit the incision used to the need in each patient rather than to fit the patient to an incision. Though the incidence is lower, dehiscence does occur after anatomic incisions. The types of incision used in cases with disruption during 1945 through 1949 are given in table 4; the incidence of dehiscence in each is not known. Although in the largest number of cases dehiscence followed a vertical rectus incision, a muscle-splitting rectus incision is widely used at the clinic. We favor retraction rather than splitting the muscle when a rectus incision is made; however, in 7 cases dehiscence followed such incisions.

In period II, 58 (61.7 per cent) incisions were in the upper zone of the abdomen, 12 (12.8 per cent) in the middle zone and 24 (25.5 per cent) in the lower zone.

An increased incidence is said to follow secondary incisions. During the years 1945 through 1949 there were 5 cases (5.3 per cent) of dehiscence after secondary incision; no incidence can be cited.

TABLE 4.—*Type of Incision in Cases with Dehiscence*

Type of Incision	Cases	Deaths	
		No.	%
Vertical (rectus)	72	15	20.8
Vertical (midline)	10	2	20.0
Oblique	7	0	0
Transverse	5	0	0
Total	94	17	18.1

Trauma to Tissue.—When tissue is traumatized at operation there result inflammation, necrosis and exudation which cause slowing of wound healing by effect on fibroblastic activity and by mechanical separation of tissue. Trauma from rough retraction, ligation of large pieces of tissue, rough handling of tissue, too hot water and chemical irritants should be avoided.

Closure.—1. Suture Material: The controversy continues over the relative merits of surgical gut versus nonabsorbable suture materials such as cotton, silk and wire. Certainly there are advantages and disadvantages to each. We feel that technic is of far greater importance than the material used.

In the use of surgical gut one must be alert for certain dangers. The suture may be defective in manufacture. This material should not be used dry, for it will crack and break or allow access of lytic substances to its interior. It should not be soaked excessively or in too hot water. One should not use too large a surgical gut suture.

Since the report of Kraissl, Kesten and Cimiotti [8] on the relation of surgical gut sensitivity,[9] some authors have stressed allergy as a chief factor in dehiscence.

7. Singleton, A. O., and Blocker, T. G., Jr.: The Problem of Disruption of Abdominal Wounds and Postoperative Hernia: A Review of 9,000 Consecutive Abdominal Incisions, J. A. M. A. **112**:122-127 (Jan. 14) 1939.

8. Kraissl, C. J.; Kesten, B. M., and Cimiotti, J. G.: The Relation of Catgut Sensitivity to Wound Healing, Surg., Gynec. & Obst. **66**:628-635 (March) 1938.

(Footnotes continued on next page)

Cases are observed in which no surgical gut is evident in separated wounds a few days after operation, and in these cases the separation probably is due to such a phenomenon. However, in the majority of cases intact surgical gut remains, and generally wound separation is on another basis.

Dehiscence may occur even though nonabsorbable sutures are used.[10] In such cases the sutures usually have pulled through the tissues because of strain or improper placement.

2. Technic: During periods I and II the technic of closure of abdominal incisions was much the same, with slight variation by different surgeons. Generally a running double strand of chromic surgical gut no. 1 was used to close the peritoneum and the posterior fascia together, and a similar suture was used in the anterior fascia. Usually a few supplemental interrupted surgical gut sutures were placed in the anterior fascia. Interrupted fine plain surgical gut sutures were used in subcutaneous tissues and silk in the skin.

3. Retention Sutures: Some surgeons have routinely used retention sutures in all abdominal closures, while other surgeons use them only on indication. In 23 cases (24.5 per cent) with disruption during the years 1945 through 1949 retention sutures had been inserted. Retention sutures in these cases usually prevented evisceration but not wound separation. One can speculate whether retention sutures prevented dehiscence in other cases.

4. Accuracy: Accurate closure of abdominal incisions is the most important preventive of wound separation. Twenty-three years ago, also before the Western Surgical Association, Freeman[11] talked on this subject. He stressed that inadequate closure of the peritoneum, with a gap in the suture line, usually is the primary cause of postoperative rupture of abdominal incisions. The omentum insinuates itself through the suture line, and because of progressive congestion that follows, it acts as a wedge. When a precipitating strain occurs, the wound disrupts. This hypothesis has been accepted by many authors, but it is reemphasized.

In closing the abdomen it is important to have adequate relaxation to secure accurate approximation of the peritoneum. Otherwise, the sutures partially or completely pull through the tissues then or later and leave a gap. The sutures should be placed close enough to avoid gaps. Omentum or preperitoneal fat should not be included between the edges of peritoneum. If sutures are placed too tightly, they will necrose through the tissue. Inherently weak posterior fascia may be present, and closure of such an abdomen is less secure than closure of a more normal abdomen. Knots should be tied accurately. Although Kennedy[12] reported remarkable success with sutures through and through the abdominal wall alone, his results have not been duplicated, and we believe that accurate closure of the abdominal wall in layers is to be striven for.

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9. Henry, M. G.: Allergic Phenomena in Relation to Abdominal Wound Evisceration: Case Reports and Experimental Work, Am. J. Surg. **64**:118-128 (April) 1944. Hopps, H. C.: Role of Allergy in Delayed Healing and in Disruption of Wounds: I. Antigenicity of Catgut, Arch. Surg. **48**:438-449 (June) 1944.

10. D'Ingianni, V.: Wound Disruption Following Cotton Sutures, Am. J. Surg. **69**:137 (July) 1945.

11. Freeman, L.: The Cause of Postoperative Rupture of Abdominal Incisions, Arch. Surg. **14**:600-604 (Feb.) 1927.

12. Kennedy, J. W.: Tragedies of the Abdominal Incision, Am. J. Surg. **25**:512-520 (Sept.) 1934.

5. Drain: If the sutures are placed too tightly around a drain they may cut through the tissue, or if they are too loose the omentum may protrude along the drain and act as a wedge. The draining material may weaken the suture material. During period II drains through the incision were present in 29 cases (30.9 per cent). The role of drains in dehiscence is difficult to evaluate, for often it is in the complicated cases that drains are used and in these cases other factors coexist.

POSTOPERATIVE FACTORS

Increased Intra-Abdominal Pressure.—Abnormal strain on an abdominal incision is produced by excessive coughing and sneezing, retching and vomiting, hiccup or intestinal distention. One or more of these factors usually is present in cases with wound separations, as noted in table 5; the incidence of strain in all cases was 78.8 per cent in period I and 81.9 per cent in period II. Such strain may be the primary factor, being severe enough to disrupt wounds carefully closed with any suture material. However, increased intra-abdominal pressure usually is a precipitating cause, forcing omentum and finally bowel through gaps in the suture line. Increased pressure also is produced by intra-abdominal fat deposition.

TABLE 5.—*Causes and Incidence of Strain on Wound*

	1925-1929		1945-1949	
Cause of Strain	No.	Per Cent of 52 Cases	No.	Per Cent of 94 Cases
Cough	27	51.9	43	45.7
Retching and vomiting	19	36.5	39	41.5
Distention	5	9.6	30	31.9
Total cases with strain *	41	78.8	77	81.9

* Since some patients had more than one cause of strain, these totals are not the same as the sum of the figures above.

Activity.—Severe strain on the wound may be produced by a fall or by excessive activity as seen in delirium and may cause wound separation.

Early ambulation has become a widespread practice. It was accepted with reservation at first, because increased dehiscence was feared. Experimental and clinical evidence indicates no increased incidence.[13] Perhaps the reverse is true, by helping prevent such complications as atelectasis and distention. In no case during the years 1945 through 1949 was it felt that early ambulation contributed to wound separation.

Infection.—Wound infections may cause disruption by delaying healing and by action on suture material; this is the primary cause in occasional cases. Suppuration is seldom seen, but low grade infection may exist without suppuration, and its role is difficult to ascertain. Grossly infected wounds were present in 2 cases (3.8 per cent) in period I and in 3 cases (3.2 per cent) in period II.

Hematoma.—Although a possible cause, hematoma in cases with dehiscence was not encountered.

13. Burch, J. C., and Bradley, C. F.: Wound Disruption and Early Ambulation, Ann. Surg. **125**:768-777 (June) 1947. Royster, H. P.; McCain, L. I., and Sloan, A.: Wound Healing in Early Ambulation, Surg., Gynec. & Obst. **86**:565-570 (May) 1948.

DIAGNOSIS

Occasionally the diagnosis of dehiscence is made in a patient apparently convalescing well, when he complains that "something gave way," and inspection reveals loops of small intestine lying on the abdomen.

Usually, however, the patient has not done well since operation. Instead of feeling better, he continues to complain of incisional and generalized abdominal pain, nausea and vomiting, and bloating. Diarrhea may occur, but distention usually is encountered and intestinal obstruction may develop. It frequently is difficult to determine whether wound separation is the cause or effect of the symptoms. The patient often continues to have an unexplained low grade fever.

The most pathognomonic sign of wound disruption is serosanguineous drainage. Such drainage was noted in 26 cases (50.0 per cent) in period I and in 49 cases (52.1 per cent) in period II. Separation of the edges of fascia or a loop of bowel occasionally can be palpated in the wound while the dermal sutures are in place.

Wound separations begin immediately or within two or three days after operation in the majority of cases. Although frequently suspected earlier, confirmation often is not possible until the dermal sutures are removed. The majority of cases are evident between the fifth and tenth postoperative days. In period I there were two cases of dehiscence during the first through the fourth postoperative day, 32 cases during the fifth through the tenth postoperative day and 18 cases after the tenth postoperative day, with a range from the fourth through the fourteenth postoperative day. In period II there were 5 cases during the first through the fourth postoperative day, 65 cases during the fifth through the tenth postoperative day and 24 cases after the tenth postoperative day, with a range from the third through the seventeenth postoperative day.

TREATMENT

Prophylactic Measures.—All possible factors which contribute to dehiscence should be eliminated or avoided. Malnutrition, avitaminosis, dehydration and anemia should be corrected with forced feedings or intravenously administered preparations as necessary before operation. Diabetes should be controlled. Obese patients should reduce their weight before elective operations. Elective operations should be postponed until bronchitis is alleviated. The patient should remain as active as possible until operation.

At operation anatomic incisions should be used when optimal exposure can be obtained. Trauma to tissue should be avoided. Most important, an accurate closure of the peritoneum without tension should be secured. Preferably, drains should be brought out through a stab wound. Retention sutures should be employed in cases with preoperative cough, debility, extreme obesity or advanced carcinoma.

Postoperative measures to prevent atelectasis, such as encouraging deep breathing, turning frequently, avoiding heavy sedation and early ambulation, are important. We agree with Phetteplace [14] that one should not encourage coughing routinely. However, if atelectasis occurs, coughing should be employed under supervision with the abdomen supported. If distention or nausea and vomiting occur, a gastric tube should be passed and suction applied. We do not use a tube routinely in abdominal cases. If an indication develops, however, a tube should be passed early. Routinely after abdominal operations we employ a scultetus binder until the wound is healed.

14. Phetteplace, C. H.: Postoperative Wound Disruptions at Sacred Heart Hospital: Report of a 5 Year Study, Northwest Med. **49**:38-41 (Jan.) 1950.

Resuture.—If the patient's condition warrants it, the treatment of choice for wound separation is resuture. Secondary closure of the incision prevents further separation, there is complete replacement of the bowel at once, hospitalization is decreased and fewer ventral hernias develop.[15]

When discovered, eviscerated bowel should be covered with a sterile dressing in cases of secondary closure and the abdomen should be taped securely to prevent further separation or evisceration. Morphine sulfate is given to alleviate apprehension. Intravenous administration of fluids is started, and a transfusion is given before or during operation if indicated. A gastric tube is inserted, the gastric contents are aspirated and the tube is left in place.

There has been much discussion concerning whether to use only through-and-through sutures or whether to close the incision with layers in addition to through-and-through sutures. We believe that the individual case should be considered. If the patient's condition is poor, if layers cannot be identified or if tissues are too friable to hold sutures, on our service only through-and-through silkworm gut sutures are inserted and tied over rubber tubes. If the reverse is true, a closure in layers is employed also. Other surgeons at the clinic routinely use only through-and-through sutures. The distribution of cases according to type of secondary closure

TABLE 6.—*Type of Closure of Dehiscence, 1945-1949*

Type of Closure	Cases	Deaths	
		No.	%
Through-and-through sutures only	44	9	20.5
Through-and-through sutures, closure of fascia or peritoneum or both	47	8	17.0
Usual closure of abdomen	2	0	0
Anesthesia to replace bowel, taped only	1	0	0
Total	94	17	18.1

during period II is presented in table 6; data on the type of closure during period I were not available. In one half of the cases an attempt was made to approximate layers at least partially as well as to use through-and-through sutures, while in most of the other cases the latter were used alone.

Anesthesia is an important factor in cases of secondary closure, a second major operation on an already sick patient. Such pulmonary conditions as bronchitis, pneumonia or atelectasis often are present. Good relaxation is desired to replace bowel and to get adequate closure. In period I in many cases operation was performed with the patient under ether anesthesia, although local and regional blocks and spinal anesthesia were used in a number of cases. During period II an increasing number of patients received thiopental sodium (pentothal sodium®) and curare anesthesia. This is our anesthesia of choice at present; it results in a smoother convalescence and we feel has contributed to a lower mortality rate.

In period II sulfathiazole, sulfanilamide, penicillin, streptomycin or some combination of these drugs was placed in the abdomen and incision in 43 cases (45.7 per cent). No significant difference in the outcome was noted between various drugs, but the number of cases in each group was small.

15. Fallis, L. S.: The Management of Postoperative Wound Separation, Surgery **9**:198-203 (Feb.) 1941.

In 36 cases (69.2 per cent) during period I and 70 cases (74.5 per cent) during period II, secondary closure was performed within 24 hours after diagnosis; in the other cases operation was delayed more than 24 hours, with the wound taped.

Conservative Treatment.—In addition to general supportive measures, if the patient is in poor general condition or there is a special contraindication, he should not be subjected to operation. Rather, any eviscerated bowel should be replaced under aseptic precautions, and the skin should be cleaned with ether and painted with an adequate skin antiseptic. Adhesive tape should be applied in a crisscross fashion to bring the edges of the incision together. The tapes should be changed, always with aseptic precautions, only when they become loosened. If the condition improves, secondary closure may be performed later.

Postoperative Care.—Fluids, including blood and amino acids, are given intravenously to maintain fluid and electrolyte balance and correct hypoproteinemia and anemia. Ascorbic acid in doses of 1 Gm. per day, as well as other vitamins, is given. A tube is kept in the stomach with suction until ileus is relieved. A Miller-Abbott tube is used if indicated. Oxygen is frequently helpful, especially in cases with pulmonary pathologic changes. Early ambulation is the rule, as soon as the patient is able. Finally, penicillin and streptomycin are given intramuscularly until the patient can tolerate oral medication. At that time aureomycin or terramycin is given if indicated.

During period II, 49 patients (52.1 per cent) received one or more transfusions, 84 (89.4 per cent) received antibiotics, 38 (40.4 per cent) received oxygen, 77 (81.9 per cent) received intravenously administered fluids and vitamins and a gastric tube with suction was employed in 32 cases (34.0 per cent). This is in contrast to four patients (7.7 per cent) given transfusion after secondary closure in period I. Other postoperative measures were used comparatively infrequently.

SUBSEQUENT COURSE

Hospital Mortality.—The mortality rate after dehiscence has been excessive. The average mortality rate of reported cases is 35 per cent. In our cases the mortality rate fell from 34.6 per cent during the years 1925 through 1929 to 18.1 per cent during the years 1945 through 1949. This drop to about half the former rate is due to more satisfactory anesthesia and to all measures employed postoperatively.

The mortality rate after various operations is shown in table 1. Dehiscence after operations on the colon continues to have the highest mortality rate.

The mortality rate after various types of incision (table 4) is essentially the same in cases with rectus and midline vertical incisions, while there were no deaths in the few cases with oblique and transverse incisions.

The mortality rate is higher in dehiscence with carcinoma than without carcinoma. Of 16 patients with carcinoma in period I, 7 died (43.8 per cent), while of the 36 patients without carcinoma, 11 died (30.6 per cent). Of 37 patients with carcinoma in period II, 9 died (24.3 per cent), while of 57 patients without carcinoma, 8 died (14.0 per cent).

There was no appreciable difference in mortality rate between cases in which closure was performed within 24 hours and those with delayed closure. In period I, in 36 cases in which closure was performed within 24 hours there were 12 deaths (33.3 per cent) and in 16 cases with delayed closure there were six deaths (37.5 per cent). In period II, in 70 cases in which closure was performed within 24 hours there were 13 deaths (18.6 per cent) and in 24 cases with delayed closure there were four deaths (16.7 per cent).

The mortality rate according to the type of closure is shown in table 6. Although it was slightly higher for patients whose wounds were closed with through-and-through sutures only, some of these were sicker patients.

The causes of death following closure of dehiscence in both periods are shown in table 7. Pneumonia and peritonitis are the chief causes in both groups. In some instances the cause of death was present before dehiscence, but all deaths must be attributed to secondary closure, directly or indirectly.

Second Dehiscence.—Wound separation after secondary closure occurred but once (1.9 per cent) in period I and not at all in period II. This experience is general and gratifying, although not fully explained.

Hospitalization.—During period I the average hospital stay after secondary closure was 22.7 days, with a range of 4 to 71 days. Although a shorter period was anticipated in period II, it was essentially the same, with an average hospital stay of 21.4 days and a range of 8 to 61 days.

TABLE 7.—*Causes of Hospital Deaths Following Closure of Dehiscence*

	1925-1929		1945-1949	
Cause of Death	Cases	Per Cent of 52 Cases	Cases	Per Cent of 94 Cases
Pneumonia	5	9.6	3	3.2
Pneumonia, peritonitis	3	5.8	1	1.1
Peritonitis	1	1.9	3	3.2
Subphrenic abscess	0	0	1	1.1
Empyema	0	0	1	1.1
Pulmonary embolus	4	7.7	3	3.2
Coronary occlusion	1	1.9	1	1.1
Uremia	1	1.9	2	2.1
Pseudomembranous ileocolitis	0	0	1	1.1
Cholangitis	1	1.9	0	0
Pulmonary edema	1	1.9	0	0
Debility	1	1.9	1	1.1
Total	18	34.6	17	18.1

Ventral Hernia.—Complete follow-up studies were not obtained. Of nine cases in which a ventral hernia is known to have developed after secondary closure during period II, six followed the use of through-and-through sutures only and three followed closure with layers as well as through-and-through sutures. In view of the approximately equal number of cases in each group, though not statistically significant, it would seem that adding closure in layers helps prevent subsequent herniation.

SUMMARY AND CONCLUSIONS

Multiple factors contribute to the occurrence of separations of abdominal wounds, as brought out in this study of 52 cases of dehiscence occurring at the Mayo Clinic during the years 1925 through 1929 and 94 cases during the years 1945 through 1949. We suspect that incomplete approximation of the peritoneum and the posterior fascia during closure is one of the most important causes of disruption of an abdominal wound. Increased intra-abdominal pressure, caused by excessive coughing, vomiting or intestinal distention, usually is present as a precipitating cause. In the presence of hypoproteinemia or avitaminosis C, a less potent precipitating cause is necessary to disrupt a wound. Many other factors have been implicated and undoubtedly have a role in dehiscence in occasional cases.

The treatment of choice, if the patient's condition warrants it, is secondary closure of the abdominal wound. Taping of the abdominal wall to approximate the edges of the wound is indicated if an operation in contraindicated.

A mortality rate of 34.6 per cent in patients with secondary closure during the years 1925 through 1929 has been reduced to 18.1 per cent in cases occurring during the years 1945 through 1949. Improved anesthesia and postoperative measures have improved the outlook following operation for this infrequent but serious complication of laparotomy.

DISCUSSION

DR. ARNOLD JACKSON, Madison, Wis.: This subject is timely and is important to all of us. I have had an opportunity to study it, because in our group there are men trained in different schools and institutions, and they use different technics and different anesthesias.

I agree with Dr. Mayo that the type of suture does not make any particular difference, whether it is silk, surgical gut, cotton or wire. I disagree, however, on the point of early ambulation. I think that is an important factor. In patients who get up the first or the second day the wound heals much better because the circulation to the wound is improved. The reason why we used to see so many eviscerations 15 and 20 years ago was because patients were kept in bed 10 or 12 days. I am sure of that.

I think the anesthesia deserves mention. Dr. Mayo pointed out that vomiting and cough are important factors in causing evisceration; I agree. We have more vomiting and more coughing in patients who receive inhalation anesthesia than in those given spinal anesthesia. Both early ambulation and spinal anesthesia are important factors. I do not think that tension sutures help. Two or three of our group use tension sutures, and it seems to me that they have more eviscerations than when those sutures are not used.

Dr. Starr Judd many years ago gave up the use of tension sutures and instead used interrupted sutures in the fascia and peritoneum. The sutures should be of small caliber, preferably of chromic surgical gut.

DR. T. G. ORR SR., Kansas City, Kan.: I believe that abdominal distention is one of the most important factors in dehiscence of wounds; at least it has been in my experience. Perhaps we do not have as many disruptions as we had formerly, because we now use the stomach tube and suction, and this tends to prevent distention. Dr. Wangensteen's method of gastric decompression is extremely valuable to promote abdominal wound healing.

As far as absorbable or nonabsorbable sutures are concerned, I doubt if the results are much different. I do believe personally that the nonabsorbable sutures are better than surgical gut. When there is distention, however, any type of suture may not hold. Not only will the sutures give way, but the tissues will necrose because of prolonged distention which shuts off the blood supply to the tissues.

DR. J. M. WINFIELD, New York: In 1939 Dr. John Hartzell, of Detroit, and I reviewed the world literature on wound disruption, comprising 1,458 cases. Thirty-three of these cases Dr. Hartzell and I observed personally. We would concur heartily with all the things that have been said; that is, there is a certain amount of confusion as to just what does cause a wound disruption. However, I should like to emphasize what Dr. Orr said. I would go a step further and say that the long, balloon-tipped tube is the tube which I believe keeps the distention down most satisfactorily, not just the gastroduodenal suction of Wangensteen. I cannot help but feel that distention is a definite factor in disruption.

I happen to be an advocate of the modified transverse incision. I also believe that this type of incision more or less guards against wound disruption.

Dr. Hartzell had the idea, on the basis of the suggestion by Sokoloff and many other observers, that a deficiency in vitamin C might be a factor. We then followed up 20 patients with disruptions and found that 18 to 19 of them had a deficiency in plasma vitamin C. There also was a reduction in serum protein levels. Of 200 operative patients picked at random, 20 per cent had carcinoma or peptic ulcer, duodenal or gastric, and all these had a reduction in vitamin C level. These two factors, vitamin C and protein levels, I am sure are just parts of the general picture that may produce wound disruption.

EFFECT OF SOAPS CONTAINING HEXACHLOROPHENE ON WOUNDS AND BURNED SURFACES

R. RUSSELL BEST, M.D.
JOHN D. COE, M.D.
AND
GEORGE B. McMURTREY, M.D.
OMAHA

CLINICAL research and experience have established the value of bar and liquid soaps containing hexachlorophene in the surgical scrub and in the preoperative preparation of the skin, as shown by Seastone,[1] Traub,[2] Best [3] and others.[3a] We have continued our experiments, directing our attention to the effect and value of these soaps on tissue surfaces, including wounds and burns. A report will be made on the reaction of various bar and liquid soaps, including those containing hexachlorophene on open wound surfaces.

The treatment of fresh wounds, both clean and contaminated, has been well established and reported by numerous authors, including Baker,[4] Bisgard and Baker,[5] Altemeier,[6] Raine [7] and Ryan.[8] This treatment should consist of the control of hemorrhage, cleansing of the wound, débridement of devitalized tissues and

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From the departments of surgery and anatomy, University of Nebraska College of Medicine.

Read at the Fifty-Eighth Annual Meeting of the Western Surgical Association, Minneapolis, Dec. 1, 1950.

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5. Bisgard, J. D., and Baker, C. P.: Treatment of Fresh Traumatic and Contaminated Surgical Wounds, Surg., Gynec. & Obst. **74**:20-26, 1942.

6. Altemeier, W. A.: Treatment of Fresh Traumatic Wounds, J. A. M. A. **124**:405-408, 1944.

7. Raine, F.: Fundamental Principals in the Treatment of Traumatic Wounds, Wisconsin M. J. **46**:1026-28, 1947.

8. Ryan, T. C.: Management of Wounds and Wound Healing, U. S. Nav. M. Bull. **47**:991-997, 1947.

surgical repair with sutures and immobilization. White bar soap has been accepted as the cleansing agent to be used for washing the wounds and surrounding skin. It has been shown in previous investigation by Baker [4] that the use of tincture of green soap is detrimental to wound healing if the soap is used within the depths of the wound.

In view of the remarkable results in the control of surface bacteria with soaps containing hexachlorophene, it was felt that it might be of value in the surgical cleansing of the open wound. However, consideration must be given to three phases of this technic. First, it must be determined whether or not hexachlorophene incorporated in soap exerts a detrimental effect on tissues or retards wound healing. Secondly, it must be determined whether the bacteriostatic and bactericidal effectiveness of hexachlorophene is significantly influenced by the presence of tissue serum. Third, consideration must be given to the toxic effects of hexachlorophene since it can be lethal when injected intravenously.

PHASE I

It was our opinion that it was most important to prove that bar or liquid soap containing hexachlorophene does not cause a severer tissue reaction than soaps not containing hexachlorophene. This factor was investigated in the following manner.

Nineteen large white rabbits were used in this part of the experiment. One of these was a control animal in which no soap was permitted to come in contact with open wound surfaces, and the remaining 18 were divided into three groups of six animals each. The open wound surfaces were treated with the following types of soap: (1) a bland bar soap; (2) the same bland bar soap as before but containing 2 per cent hexachlorophene; (3) a liquid soap containing no hexachlorophene; (4) the same liquid soap containing hexachlorophene 5 per cent basis soap content diluted with equal parts of water; (5) the same liquid soap containing no hexachlorophene but with 5 per cent alcohol. In each group, the back of the animal was clipped and shaved for an area 8 inches (20 cm.) long and 3 inches (7.6 cm.) wide on either side of the spine. The animals were anesthetized with pentobarbital sodium (nembutal sodium®).

In the first group, five separate lacerations 2 cm. long were made on each side with a scalpel. In two animals, the right side was washed for five minutes with a bar soap containing 2 per cent hexachlorophene and sterile water; the left side was washed in a similar manner with the bland bar soap containing no hexachlorophene. In two other animals, the right side was washed with the liquid soap containing 2.5 per cent hexachlorophene basic soap content and the left side with the control liquid soap which contained no hexachlorophene. In two of these animals the right side was washed in a similar manner with the liquid soap containing 2.5 per cent hexachlorophene and the left side was washed with the liquid soap containing no hexachlorophene but containing 5 per cent alcohol.

In the second group of animals the back was prepared as described before, and the animals were anesthetized. The back was abraded on either side for an area measuring 2 by 10 cm. This was accomplished by briskly scraping the skin with the edge of the scalpel until bleeding was encountered. The various soaps were then applied to the abrasions as related in the previous paragraph.

In the third group of animals the back was prepared as described previously and the animals were anesthetized. The back was burned on either side for an area measuring approximately 2 by 10 cm. by drawing a hot soldering iron along the skin to produce a third degree burn. The various soaps were then applied to the burned surfaces as previously related.

The control animal was prepared as were the other animals and was anesthetized, incised, abraded and burned in the same manner.

In each of these 19 animals, tissue was excised from the abraded, incised or burned area at intervals of 15 minutes, 1 hour, 2 hours and 7 days. In the incised animals, the entire area of the small incision was removed so that histological study could be made. In the other two groups, material was taken for biopsy from representative areas of the traumatized tissue. Tissue from the control animal was likewise taken at the described intervals. These several hundred specimens of tissue were then studied microscopically.

Histological interpretation of wound healing is difficult to evaluate because of the variable factors represented in the process of wound healing. Infection and/or inflammatory exudate obscure the reparative processes after any length of time. Therefore, biopsies at 15 minute, 1 hour and 2 hour intervals were chosen to evaluate the tissue reaction to the various soaps. The seven day biopsy was chosen to picture the later results.

The first change which became evident in the tissues was engorgement of the blood vessels; then the connective tissue fibers became swollen, showing some hyalinization. After this there was an extrusion of fluid into the tissues, with resultant edema. Soon some of the serum extruded onto the surface, and a surface exudate appeared. A later result was the mobilization of the phagocytes, round cells and polymorphonuclear cells. The seven day biopsy showed varying degrees of fibroblastic activity, and new connective tissue marked the beginning of histological wound repair. The tissue reactions were graded in an attempt to give a comparative evaluation and to determine which soaps were most irritating (tables 1, 2 and 3).

The tissue reaction in the incised wounds which were washed with the testing soaps showed little difference from that in the wounds of the control animal. Examination of the slides reveals an earlier tissue reaction at 15 minutes when tissues come in contact with any soap, and at the two hour interval the reaction was a little more marked than in the control animal. At the seven day interval, the acuteness of the local reaction had greatly subsided and one could not make any differentiation. There was no difference in tissue reaction between the plain bar and plain liquid soaps, or between these soaps and the bar and liquid soaps containing hexachlorophene. Particular attention was paid to any difference in tissue reaction between the bar and liquid soaps containing hexachlorophene, and nothing of significance was evident. However, in wounds which had been in contact with liquid soap containing 5 per cent alcohol the microscopic sections revealed a decided increase in tissue reaction. The edema, exudate and vessel engorgement were definitely more pronounced.

The tissues of the animals that had been abraded revealed a rather similar microscopic picture to that seen in the control animal, except where liquid soap containing 5 per cent alcohol was the washing agent. Here the tissue reaction was definitely more marked, similar to that seen in the incised wounds in which the

same soap was used. We were unable to distinguish any difference in tissue reactions to plain bar or plain liquid soaps or to the bar and liquid soaps containing hexachlorophene. In general, the tissue reaction in the abraded wounds is somewhat more marked than that in the incised wounds, and this can be explained by the increased mechanical destruction.

Biopsies on the burned animals revealed a significant increase in local tissue reaction over that of the incised and abraded animals. Without question, the severity

TABLE 1.—*Tissue Reaction of Incised Wounds* *

Time	15 Minute Reaction	1 Hour Reaction	2 Hour Reaction	7 Day Reaction
Control—no soap	M	M	M S	M
Bar soap—no hexachlorophene	M	M S	M S	M
Bar soap with hexachlorophene	M	M S	M S	M
Liquid soap—no hexachlorophene	M	M S	M S	M
Liquid soap with hexachlorophene	M	M S	M S	M
Liquid soap with 5% alcohol	S	S	S	M S

Reaction of tissues based on microscopic study for engorgement of vessels, edema, hyalinization, cellular infiltration and surface exudate. Consideration was also given to the gross appearance of tissues.
* M indicates mild, M S moderately severe and S severe.

TABLE 2.—*Tissue Reaction of Abrasions*

Time	15 Minute Reaction	1 Hour Reaction	2 Hour Reaction	7 Day Reaction
Control—no soap	M	M S	M S	M
Bar soap—no hexachlorophene	M	M S	M S	M
Bar soap with hexachlorophene	M	M S	M S	M
Liquid soap—no hexachlorophene	M	M S	M S	M
Liquid soap with hexachlorophene	M	M S	M S	M
Liquid soap with 5% alcohol	S	S	S	M S

Reaction of tissues based on microscopic study for engorgement of vessels, edema, hyalinization, cellular infiltration and surface exudate. Consideration was also given to the gross appearance of tissues.

TABLE 3.—*Tissue Reaction in Burns*

Time	15 Minute Reaction	1 Hour Reaction	2 Hour Reaction	7 Day Reaction
Control—no soap	M S	M S	M S	M
Bar soap—no hexachlorophene	M S	S	M S	M
Bar soap with hexachlorophene	M S	M S	M S	M S
Liquid soap—no hexachlorophene	M S	M S	S	M S
Liquid soap with hexachlorophene	M	M S	M S	M
Liquid soap with 5% alcohol	S	S	S	S

Reaction of tissues based on microscopic study for engorgement of vessels, edema, hyalinization, cellular infiltration and surface exudate. Consideration was also given to the gross appearance of tissues.

of this type of injury was the major factor in this increase in tissue reaction. Here again the liquid soap containing 5 per cent alcohol evoked a severer tissue reaction.

Gross examination of all these wounds revealed no difference in healing properties. The wounds which had been treated with hexachlorophene healed as promptly as those treated with the control soaps or as the controlled wounds. There was no increase in tissue induration or gross evidence of local tissue reaction.

In evaluating the results of this experiment, the animals that were incised were the most satisfactory to study. In the abraded wounds, and more particularly in the burned surfaces, the local mechanical destruction was sufficient to make interpretation of the results less satisfactory.

PHASE II

It was stated by Seastone that the bacteriostatic effectiveness of hexachlorophene is decreased a hundredfold by the presence of 1 per cent serum in a culture medium. In a series of experiments in the Armour Laboratories [9] it was shown that bacteria counts were low on plain glucose tryptone agar plates when a hexachlorophene soap solution plus the culture mixture was used. If 1 per cent blood serum was added to the agar plates, the counts were much higher, indicating there was a neutralization of the hexachlorophene. There was little difference when the blood serum was increased to 10 per cent. These are in vitro experiments, and the neutralization of the hexachlorophene by the presence of blood serum cannot be considered conclusive for conditions such as exist in wound washing. We have attempted to evaluate the use of hexachlorophene soaps in wounds contaminated with a virulent strain of Streptococcus and in which blood serum is always present. The method of testing was similar to that described by Gordon and his associates.[10]

Seventy white mice were used, which were divided into seven groups of 10 mice each. The bacteria used was the streptococcic strain Richards, which regularly kills mice after superficial infection of wounds. The animals were wounded by

TABLE 4.—*Mice Surviving Streptococcic Contamination*

Survival Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Control—no soap	9	8	6	5	5	3	1	0	0	0	0	0	0	0
Bar soap—no hexachlorophene	9	9	9	7	7	6	5	4	4	4	4	4	3	2
Bar soap with hexachlorophene	10	9	9	8	8	6	5	3	3	2	1	1	0	0
Liquid soap—no hexachlorophene	10	9	7	7	5	4	4	3	3	2	1	1	0	0
Liquid soap with hexachlorophene	10	10	10	9	9	8	8	7	4	4	3	3	2	2
Liquid soap with alcohol 5%	10	10	10	10	7	7	7	7	6	5	4	3	2	2
Saline	10	8	8	6	4	2	1	..	..	..	..	..	..	..

Wounds on the mice were contaminated with a virulent Streptococcus. In the control animals the wounds were not irrigated. In the other animals the wounds were washed with various soaps or saline immediately at 3 hours and at 24 hours. The control animals were all dead by the eighth day, but there were survivors in the other groups.

Note survivals on the fourteenth day.

grasping the loose skin on the back of the animal with forceps and snipping through the skin with scissors in order to leave a lozenge-shaped area of exposed subcutaneous tissue measuring from 1 to 2 cm. From 1 to 3 drops, or an amount necessary to flood the wound, of a washed culture of the Streptococcus was placed on this wound. Then the base of the wound was scarified by scratching with a needle. In groups of 10, the contaminated wounds were treated in the following manner.

The first 10 mice served as the control and were wounded and contaminated but no further attention was given to them. Then in groups of 10 mice the contaminated wounds were washed for three minutes with a bar soap containing no hexachlorophene, a bar soap with hexachlorophene, a liquid soap without hexachlorophene, a liquid soap with hexachlorophene and a liquid soap with 5 per cent alcohol, and finally a group of 10 were washed with plain saline solution. These wounds were washed again three hours later, and again at the 24 hour interval.

9. The Armour Laboratories: Personal communication to the authors.

10. Gordon, J.; McLeod, J. W.; Mayr-Harting, A.; Orr, J. W., and Zinneman, K.: The Value of Antiseptics as Prophylactic Applications to Recent Wounds, J. Hyg. **45**:297-306, 1947.

In table 4 the survival of the animals is noted up to the 14 day period. It can be noted that from 48 to 72 hours elapsed before there was any significant mortality. This coincides with previous experience of others and ourselves, namely, that the septicemia of this infection does not reach lethal proportions until approximately that time. It is interesting to note that at seven days there is only 10 per cent survival of the control group and in the group washed with saline solution, whereas the group treated with liquid soap containing hexachlorophene shows an 80 per cent survival rate. At the same time there is a 50 per cent survival with both bar soaps. The liquid soap (medicinal, U. S. P.) gave a survival rate of 40 per cent and the liquid soap containing 5 per cent alcohol a survival rate of 70 per cent.

The 10 day interval reveals all the control group dead, with a 40 per cent survival rate from the liquid soap containing hexachlorophene. At the same time there was a 50 per cent survival with the liquid soap containing alcohol and 20 per cent survival with the bar soap containing hexachlorophene. It must also be noted that there was a 40 per cent survival when plain bar soap was used. With saline irrigations, all animals died.

At 14 days after the wounding there was a 20 per cent survival with the liquid soap containing hexachlorophene, the bland bar soap and the liquid soap containing alcohol. The animals in all other groups were dead.

This small series of experimental animals has provided an interesting result in the treatment of contaminated wounds with soaps containing hexachlorophene. No far-reaching conclusions can be drawn, but from an examination of the survival rates in the first seven days it seems that soaps containing hexachlorophene will provide a valuable adjunct in the treatment of fresh contaminated wounds. It must be realized that none of these animals received any chemotherapy and that if the early septicemia can be prevented, delayed or minimized by the use of hexachlorophene soaps in wound washing, then that in itself is of considerable value. The study represents a matter of quantitative contamination wherein the hexachlorophene soaps diminish the numbers of bacteria to which the body is subjected and as a result enhance the effectiveness of ordinary chemotherapeutic agents.

At the seven day interval the liquid soap containing hexachlorophene showed an 80 per cent survival, the best of the group, and this possibly is due to the fact that liquid soap provides better contact of the hexachlorophene with the exposed tissues. At the same time interval, the liquid soap containing alcohol showed a 70 per cent survival, essentially the same as that given by the hexachlorophene. However, the deleterious effect of the alcohol as shown in this paper would make one hesitate to suggest its use. The bar soap containing hexachlorophene showed the same survival rate as the bar soap containing no hexachlorophene. However, that survival rate was four times that of the control animals, which is still of considerable significance.

PHASE III

Hexachlorophene has been found to be nonirritating and nontoxic when applied to the intact skin. However, an occasional person will be sensitive in some way and in some degree to this compound, which is true of every compound or drug used. Gump[11] has reported this compound to be relatively nontoxic when given

11. Gump, W. S.: The Development of a Germicidal Soap, Soap and Sanitary Chemicals **21**:36-50, 1945.

orally to guinea pigs. Price and Bonnett [12] found that hexachlorophene injected intravenously is highly toxic in dogs. The amount which could be absorbed by washing raw surfaces would probably be minimal. However, this phase of the problem is now being investigated, with the use of a bar of radioactive hexachlorophene soap, and we hope to be able to determine the site and extent of any absorption. Our animals did not give evidence of any toxic effects, and we have not hesitated to use the soap routinely in washing wounds of patients. There has been some hesitance in advocating its use in the management of extensive burns, but for the smaller burns there seems to be no contraindication.

COMMENTS

In all methods of wound management, the decision of whether to wash the wound itself is most often evaded. One author, Ryan, suggested that both the skin and the wound should be washed. Another, Raine, stated that none of the cleansing solution should enter the wound itself. It has been shown by Baker that a bland soap causes only minimal tissue reaction when used on exposed tissue, and our studies support this contention. In view of the remarkable effect of bar soap containing 2 per cent hexachlorophene and liquid soaps containing 5 per cent hexachlorophene diluted with equal parts of water on surface bacteria, it is felt that their use in contaminated wounds will promote better control of any potential infection. A single wound washing does not permit the cumulative effect that is so important in the surgical scrub, but it still can have value. As the experimental work progressed and we were unable to differentiate any unfavorable tissue reactions by the microscopic studies, we gradually began cleansing all accidental wounds with bar or liquid soap containing hexachlorophene. There is no good measuring stick for later wound healing, and the general observation for delayed healing and extent of inflammatory reaction must be accepted. We have not noticed any delay in the healing process or any change in the inflammatory reaction around wounds. Likewise, we are unable to say that any certain wound would have been infected if a soap containing hexachlorophene had not been used. However, the potential for diminishing wound infection is present, and with the experience of others as well as ourselves in regard to the value of such soaps in the surgical scrub, we recommend either the bar or the liquid soap containing hexachlorophene in the routine cleansing of accidental wounds and the surrounding skin under both civilian and military conditions.

We have tried to evaluate the effect of soaps containing hexachlorophene on burned surfaces. This is difficult to do by studying the tissue reaction on microscopic sections. However, by deduction, there would seem to be no contraindications to their use. We have not had sufficient experience with such soaps in the management of burns to make a statement at this time. The possible toxic factor in extensive burns needs some study.

SUMMARY

Histological evidence presented by this experiment indicates that the presence of 2 per cent hexachlorophene in bar soap or 5 per cent in liquid soap (diluted with equal parts of water) exerts no influence on the amount of tissue reaction. Gross examination and histological study showed that wound healing was not delayed.

12. Price, P. B., and Bonnett, A.: The Antibacterial Effects of G-11 with Special Reference to the Production of a Germicidal Soap, Surgery **24**:542, 1948.

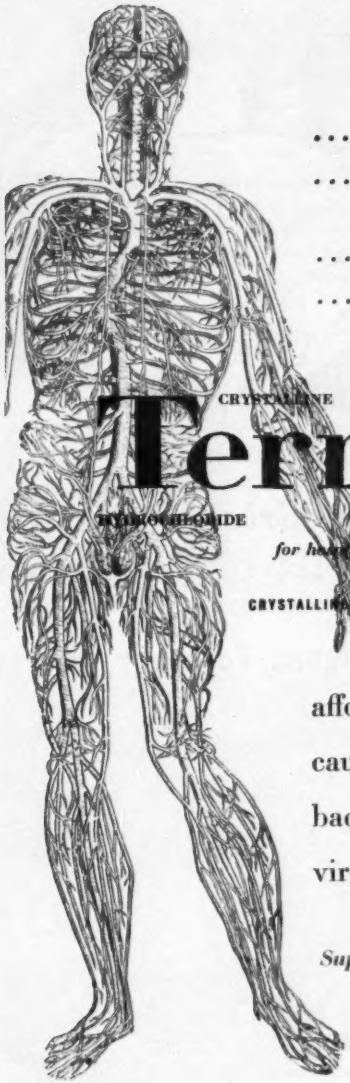
The liquid soap containing alcohol showed a more marked tissue reaction in all instances, but it is effective against pathogens. This fact becomes more impressive when we realize that tincture of green soap (U. S. P.) used in many accident wards throughout the country, contains six times this amount of alcohol. We believe that the use of this soap should be discontinued and replaced by a soap containing hexachlorophene. There was no essential difference in tissue reaction between the bar soap containing hexachlorophene and the liquid soap containing hexachlorophene.

It seems desirable that wounds be washed, as well as the surrounding skin, with a soap containing hexachlorophene, which provides a useful adjunct to wound care and reduces the early exposure to bacteria so that chemotherapy may be more effective. The usual technic of final irrigation of the wound with sterile water or saline solution is recommended.

Note.—The soaps used in these experiments were the bar soap dial,® containing 2 per cent hexachlorophene, and the liquid soap Formula 99 of Armour and Company, which contains 5 per cent hexachlorophene basis soap content and is diluted with equal parts of water before it is used.

DISCUSSION

DR. MICHAEL MASON, Chicago: I am glad to note that the actual use of soaps in open wounds is not deleterious. For a good many years we have advocated the washing out of wounds with plain bar soap, and clinically we have not seen any bad effects from the use of that agent in the cleansing of open wounds and burns. We have had no experience with the use of hexachlorophene in wounds. As far as Dr. Coe's statistics show and as far as his experimental study is concerned, hexachlorophene is not an irritant. How much added value it is to the actual mechanics of cleaning is more difficult to determine.



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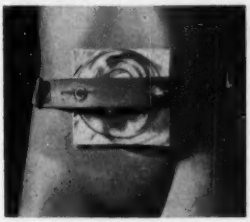

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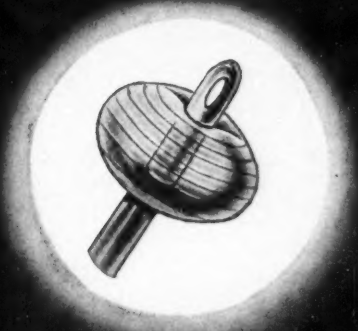

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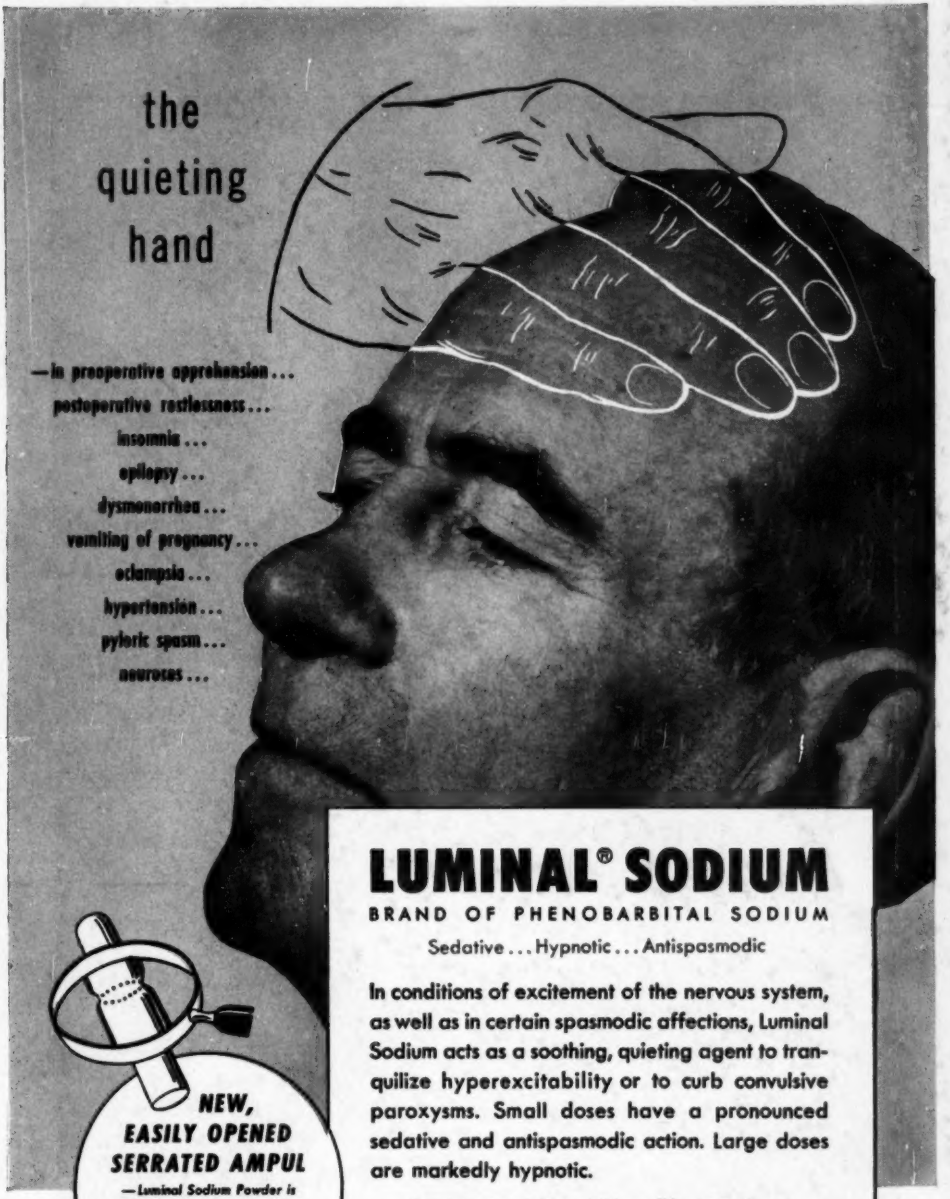

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